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By

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Elinore M. Barrett, March 1963

INTRODUCTION

The California oyster industry is an interesting example of man's adapting an otherwise unproductive part of the landscape to his benefit. His efforts to raise exotic oyster species on barren, tidal mud-flats along a coast where there is no native oyster stock of commercial value have met with both success and failure, and the industry has been marked by wide fluctuations in activity over its 110-year history.

California was the leading Pacific coast oyster producer during the latter 19th century, followed closely by Washington. Production in Oregon was comparatively insignificant (Table 1). After the decline early in this century of the San Francisco Bay oyster industry based on young oysters imported from the east coast, the California industry had a marginal existence until a major revival of the industry in the mid-1950's. At that time, large-scale plantings of young oysters imported from Japan, raised California oyster production to a level similar to that achieved in the late 19th century. By volume of production, California in 1958 was second ranking oyster producer on the Pacific coast, and seventh ranked among all United States oyster producing states (Tables 1 and 2). The latter rank was due to declining production on the east coast as well as to increased production in California.

TABLE 1
Pacific Coast Oyster Production
(Thousands of pounds of meat)

Year	*California*	*Washington*	*Oregon*	*Total*	*California as percent of total*
1888	910	427	29	1,366	66.6
1889	1,023	881	12	1,916	53.4
1890	1,059	1,037	10	2,106	50.3
1891	1,107	1,165	11	2,283	48.5
1892	1,249	1,154	11	2,414	51.7
1895	1,149	756	10	1,915	60.0
1899	2,730	688	7	3,425	79.7
1904	1,321	1,338	7	2,666	49.5
1908	728	1,323	7	2,058	35.4
1912	475	480	12	967	49.1
1915	384	715	2	1,101	34.9
1922	74	625	11	710	10.4
1923	69	737	14	820	8.4
1924	53	703	11	767	6.9
1925	57	710	10	768	7.4
1926	61	778	3	842	7.2
1927	55	669	2	727	7.6
1928	77	689	–	766	10.0
1929	53	684	9	746	7.1
1930	78	533	8	619	12.6
1931	130	1,161	6	1,297	10.0
1932	59	2,353	8	2,420	2.4
1933	86	3,012	30	3,128	2.7
1934	101	5,243	33	5,377	1.9
1935	107	5,805	19	5,931	1.8

TABLE 1—Continued

Pacific Coast Oyster Production

(Thousands of pounds of meat)

Year	California	Washington	Oregon	Total	California as percent of total
1936	104	6,612	37	6,753	1.5
1937	163	7,980	98	8,241	2.0
1938	213	8,640	204	9,057	2.4
1939	246	8,527	215	8,988	2.7
1940	192	9,388	925	10,505	1.8
1941	256	11,775	561	12,592	2.0
1942	86	10,555	138	10,779	0.8
1943	117	6,971	889	7,977	1.5
1944	89	8,273	510	8,872	1.0
1945	48	9,611	576	10,235	0.5
1946	22	13,400	130	13,552	0.2
1947	24	11,382	79	11,485	0.2
1948	66	9,639	60	9,765	0.7
1949	34	7,838	501	8,373	0.4
1950	38	7,225	976	8,239	0.5
1951	43	7,861	805	8,709	0.5
1952	45	9,138	917	10,100	0.4
1953	37	9,712	668	10,417	0.4
1954	74	10,459	436	10,969	0.7
1955	218	10,935	527	11,680	1.9
1956	755	10,605	567	11,927	6.3
1957	1,359	9,874	429	11,662	11.7
1958	1,158	9,569	508	11,235	10.3

TABLE 2

United States and California Oyster Production

Year	Volume [1]			Value [2]		
	United States	California	[3]	United States	California	[3]
1888	143,312	910	0.6	$10,804	$509	4.7
*1892	197,639	1,249	0.6	16,070	698	4.3
*1899	175,472	2,730	1.6	12,613	867	6.9
*1904	169,792	1,321	0.8	14,773	628	4.3
1908	178,207	728	0.4	12,721	337	2.6
*1915	145,253	384	0.3	12,201	173	1.7
*1923	117,709	69	0.1	13,713	24	1.8
1929	103,159	53	0.1	13,232	26	2.0
1932	68,469	59	0.1	5,976	19	3.2
*1935	79,472	107	0.1	6,782	40	5.9
1938	86,932	213	0.2	8,458	49	5.8
*1941	88,956	256	0.3	10,108	48	4.7
*1944	74,656	89	0.1	19,288	47	2.4
*1947	79,895	24	[4]	27,568	25	0.1
1950	76,415	38	[4]	29,596	36	0.1
1953	79,719	37	[4]	29,054	44	0.2
1956	75,134	755	1.0	30,884	178	0.6
1958	66,396	1,158	1.7	30,442	242	0.8

* Figures for U.S. include state totals for various years.
[1] Thousands of pounds.
[2] Thousands of dollars.
[3] California production as percent of U.S. production.
[4] Less than 0.01 percent.

TABLE 2—Continued

Rank of California Among Oyster Producing States

Year	*Number of producing states*	*Rank by volume*	*Rank by ratio of volume to value*
1888	20	13	1
*1892	20	13	1
*1899	18	10	1
*1904	20	14	1
1908	20	19	2
*1915	19	17	3
*1923	19	18	3
1929	19	18	2
1932	19	18	2
*1935	19	18	2
1938	19	16	2
*1941	19	19	4
*1944	19	19	2
*1947	19	19	1
1950	19	19	1
1953	19	19	1
1956	19	14	14
1958	19	7	16

* Figures for U.S. include state totals for various years.

Two general accounts of California's oyster industry development have been published. One was by Charles Townsend (1893), who visited the oyster growing area of San Francisco Bay a number of times during the late 1880's in the course of his work aboard the United States Bureau of Fisheries' steamer *Albatross*. The other account was by Paul Bonnot (1935), California Division of Fish and Game, whose principal contribution was a description of developments in the industry in the 1930's connected with introducing Pacific oysters from Japan and the attempt to establish a native oyster industry.

There appears to be no published account of the California oyster industry covering its entire history and utilizing all the scattered materials relating to the subject, particularly to its current condition. I have attempted to supply such an account in this paper.

OYSTERS AND GROWING AREAS IN CALIFORNIA

Location of Oyster Growing Areas

In California, oysters have been planted in shallow, protected waters where defense against destructive bat stingrays, *Myliobatis californicus*, is feasible and where generally calmer waters make working the beds easier. Oysters have been grown commercially in most of the larger protected waters along the central and northern California coast (Figure 1). Morro Bay is the most southerly producing area of any importance. The largest bay in southern California, San Diego Bay, was utilized only in a minor and generally unsuccessful way during the early period of the industry. By the 1930's when oyster growing was being revived in California, it was too polluted to be used.

For most of its history, California oystering has been centered on San Francisco Bay and the smaller estuaries of Tomales Bay and Drakes Estero (Figure 1). The first commercial oyster beds in California were established in San Francisco Bay about 1851 when Americans were beginning to settle California in large numbers and San Francisco was the largest and most important market center. When conditions in San Francisco Bay became unfavorable for growing of oysters after about 1905, attempts were made to develop other areas. Beds were established on the limited tidelands of nearby Tomales Bay beginning about 1907. In 1910 and 1911, one San Francisco Bay oyster grower, Morgan, unsuccessfully attempted to shift his oyster operations to Humboldt Bay, 280 miles to the north.

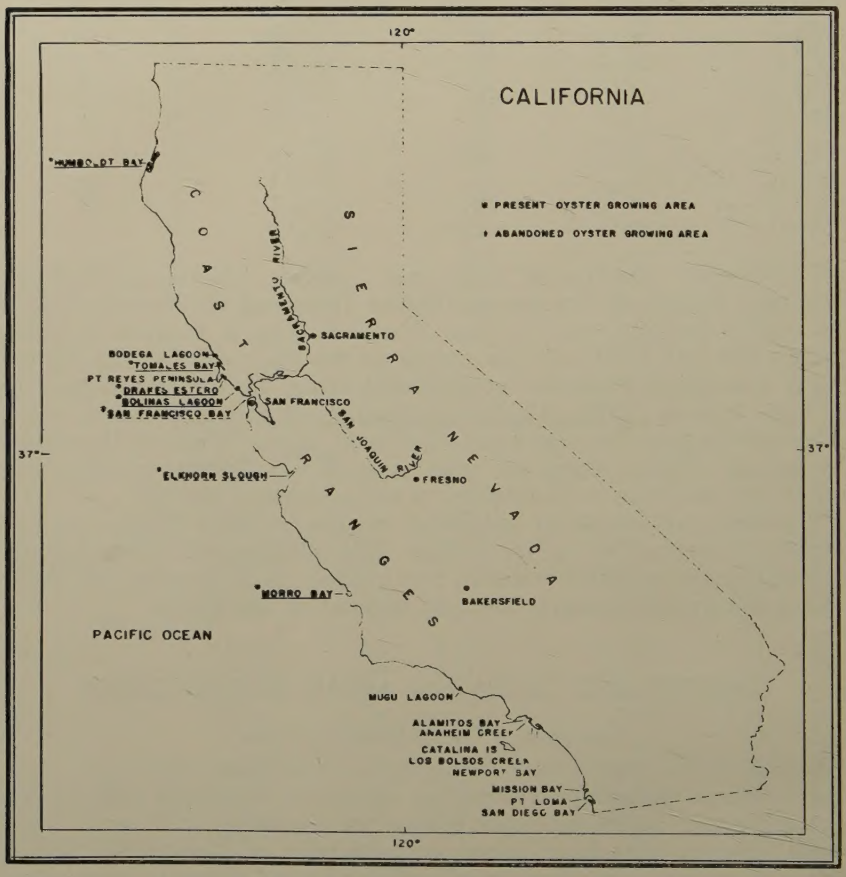

FIGURE 1. California oyster growing areas.

When Pacific oysters were introduced from Japan in the early 1930's, production spread to other areas. At that time, the California Division of Fish and Game became actively interested in reviving the oyster industry, and in conjunction with the United States Bureau of Fish-

eries, examined numerous California bays and lagoons for oyster growing potentialities. Based on these surveys and experimental plantings of Pacific seed oysters made by the Division in 1932, commercial oyster growing enterprises were established in Drakes Estero, Morro Bay, and Elkhorn Slough (Figure 1).

Humboldt Bay was restricted to native oysters as the result of a California Fish and Game Commission decision, made in the early 1930's, to foster a native oyster industry there. Exotic species were banned in order to keep the bay free of pests which could be brought in with the imported species. Also these exotic oysters, particularly Pacific oysters, are much larger than native oysters, and it was thought native oysters could not successfully compete with them.

The center of oyster production has shifted away from the San Francisco Bay area. Oystering in San Francisco Bay was completely abandoned in the late 1930's due chiefly to industrial and domestic pollution of the bay, and large-scale oystering developed in Morro Bay and Humboldt Bay beginning in the mid-1950's. Of the remaining oyster producing bays in the San Francisco area, Drakes Estero is being fully developed, but Tomales Bay has been declining in recent years.

The change in location of principal California oyster growing areas is summarized in Figure 2 which shows the relative importance of growing areas for alternate years from 1888 to 1958.

Oysters Grown in California

Three oysters have been involved in the California oyster industry (Figure 3). The oyster indigenous to the Pacific Coast of North America, *Ostrea lurida* has been the least important. The other two are exotic species, *Crassostrea virginica* from the Atlantic and Gulf coasts of North America and *Crassostrea gigas* from Japan.

O. lurida is commonly called the native oyster on the Pacific coast. The market name "Olympia" is generally applied to this species in Washington, although it is more properly applied only to those from the vicinity of Olympia on Puget Sound, the principal center where they are raised. *C. virginica* is commonly called eastern oyster and *C. gigas* is variously called Japanese oyster, giant Pacific oyster, or Pacific oyster—the last term will be used in this paper.

Oysters are sedentary bivalve mollusks which fasten to the substrate. By contractions of its adductor muscle an oyster controls the opening and closing of its valves. The adductor muscle can hold the valves tightly closed for considerable periods, varying according to the temperatures to which the oyster is subjected. When an oyster hermetically seals its valves by locking its adductor muscle, it so reduces its body functions that it can, for several days, derive the oxygen it requires from the sea water retained within its valves. This gives the oyster a defense against many enemies and unfavorable conditions. It also makes it possible to hold oysters out of water for shipping and marketing without serious injury.

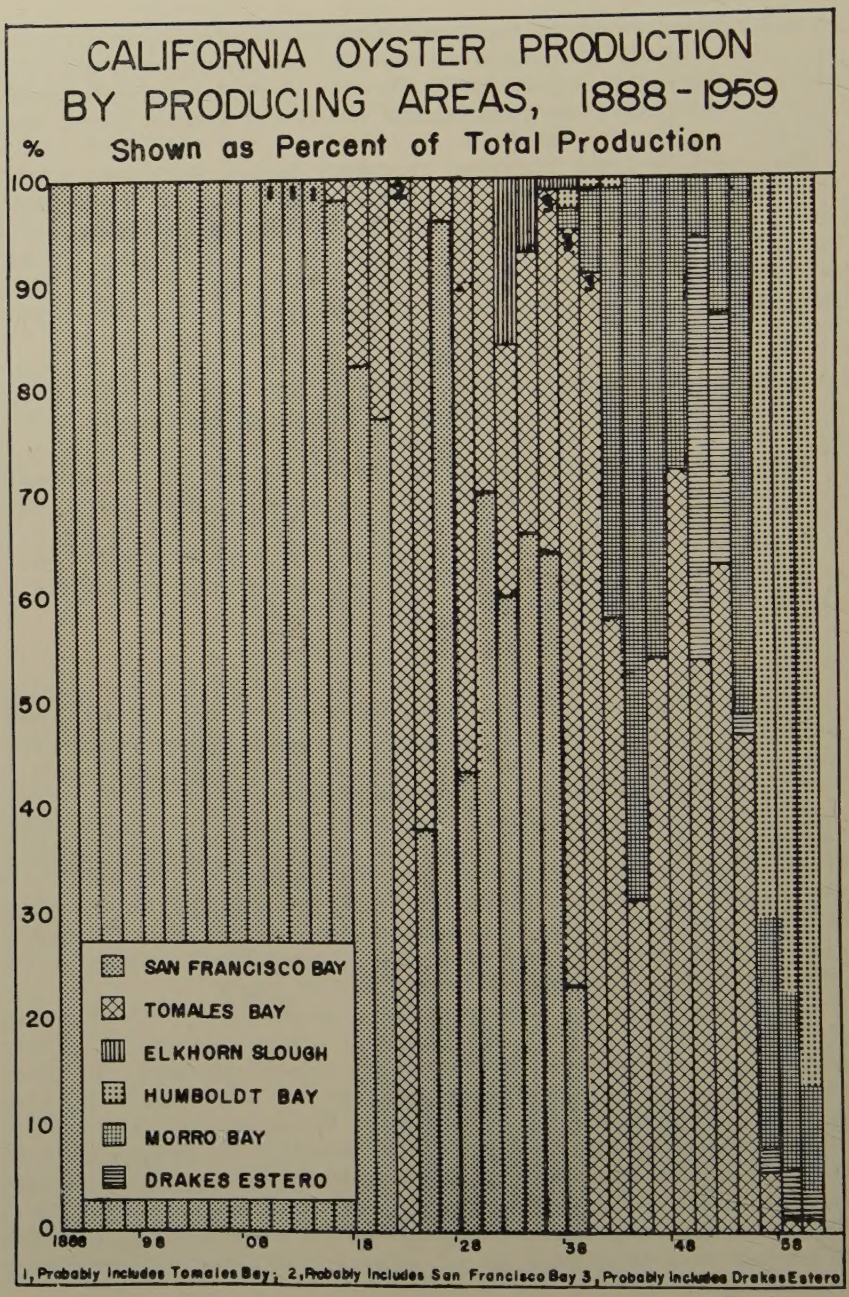

FIGURE 2. California oyster production by areas.

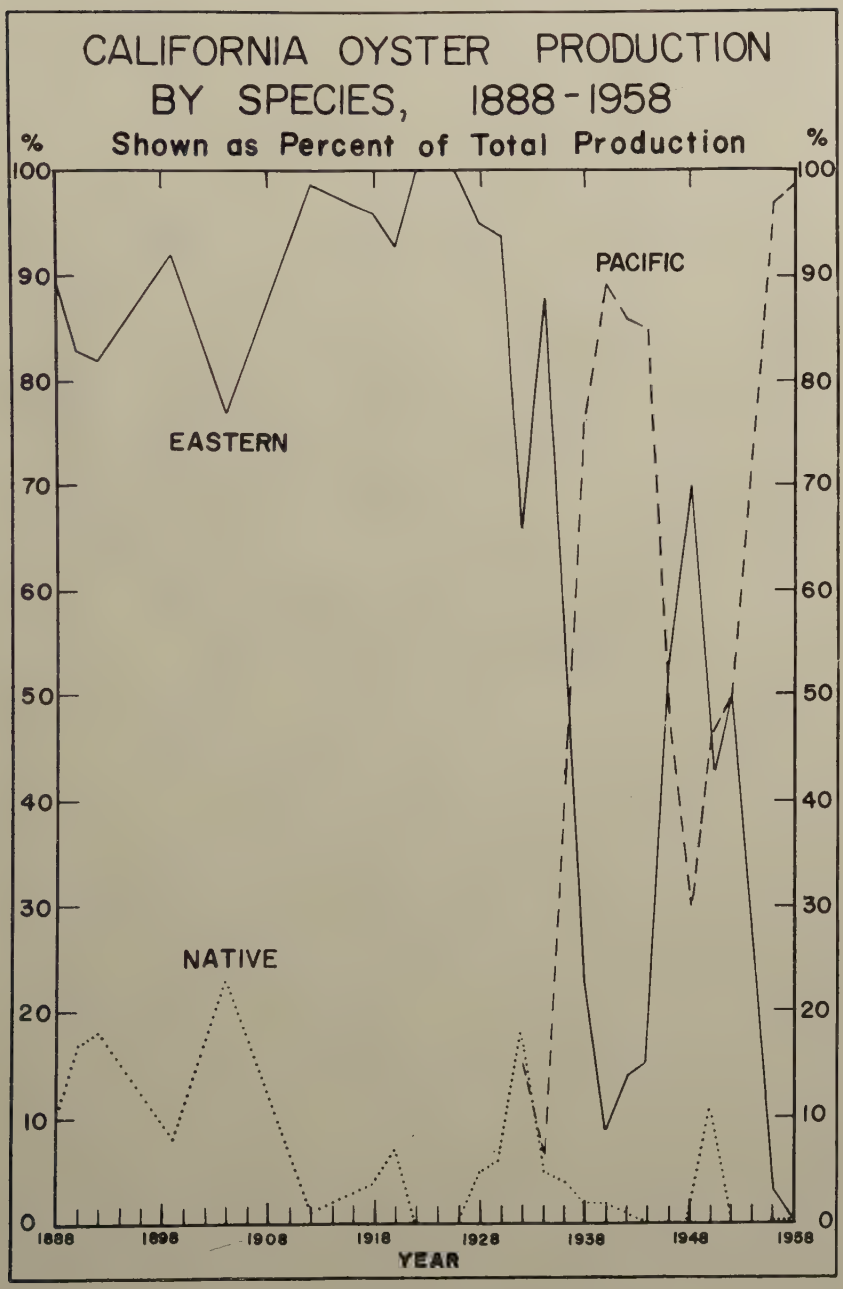

FIGURE 3. California oyster production by species.

The oyster's inner organs are enclosed in a sack-like structure, the mantle, which is, for the most part, open on all sides allowing water to pass through to the gills (Figure 4). Glands at the edge of the mantle secrete the shell material.

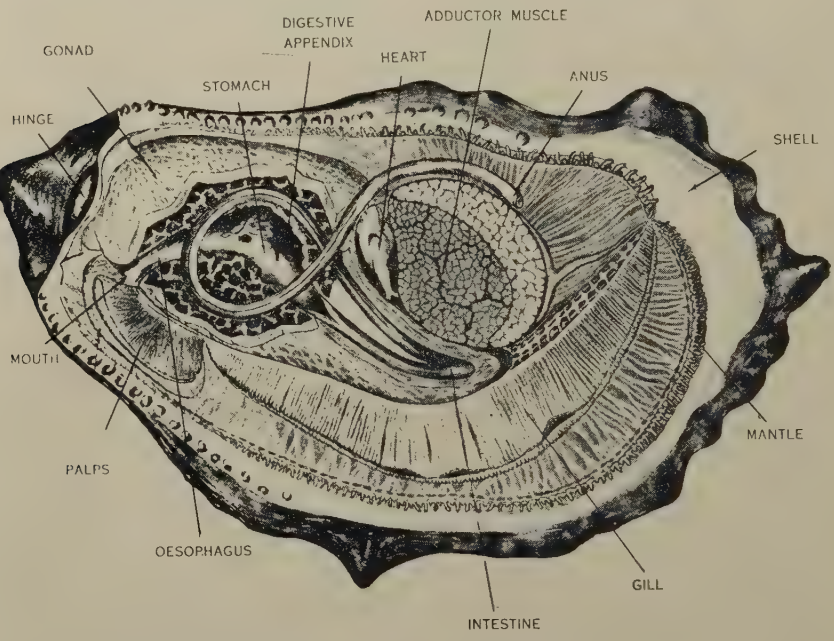

FIGURE 4. Anatomy of an oyster. *From Handbook for Oyster Farmers, Division of Fisheries, Australia.*

By means of its two gills, an oyster breathes and gets its food. Cilia on the inner sides of the gills, beating in unison, pull a current of water in through the open valves and through the gills. When an oyster is feeding, a sheet of mucus is secreted on the gill surfaces. The microscopic food particles carried in the water become entangled in the mucus and are thus "captured" by the oyster. The water then passes through pores in the gills (ostia) to the excurrent chamber, where it flushes away the fecal matter discharged by the anus. The food-containing mucus is pushed in the opposite direction toward the mouth by other cilia.

Not all of the food caught by the gills is ingested. Before it reaches the mouth, some of it is rejected by the palps, partly on the basis of particle size and shape. The food of oysters consists of plankton and detritus. Diatoms and dinoflagellates are considered preferred foods (Lackey, et al. 1952, p. 156). Coe (1947, p. 112) says this information resulted from examining oyster stomachs and intestines. However, he says, more careful investigation has proved that most of the oysters' nutrition is derived from minute particles such as detritus from disintegrated marine plant and animal cells, bacteria, minute flagellates and

other protozoa, very small diatoms, and gametes of algae and invertebrates. Larger planktonic organisms found in the digestive tract may merely pass through without digesting.

The feeding process described above is common to all three species of oysters under discussion. However, it is important to point out their feeding capacities and, hence, growth rates, differ considerably. Growth depends largely on the available food supply and conditions in the environment favoring functioning of the feeding organs, but there are differences in the oysters themselves affecting their ability to utilize the available food.

One such difference is the size of ostia in the gills. These openings, through which the current of water moves, are also the passages through which, in the spawning season, the eggs of the females pass from the gonad into the branchial (gill) chamber. The eggs of the native oyster, and hence its ostia, are larger than those of the eastern and Pacific oysters according to Elsey (1935, p. 142) who points out (p. 153) the effect of larger ostia on feeding:

"The present observations on *O. lurida* indicate that much fine material passes through the ostia. Such particles, if they pass out in the excurrent water, are lost as food and since nanno-plankton is a very important source of the oyster's nutriment, *O. lurida* is at a distinct disadvantage as compared with *O. gigas.*"

Another anatomical characteristic bearing on feeding capacity is the number and length of lateral cilia which drive water through the gill openings. The advantage of greater filtering capacity made possible with numerous, long, lateral cilia is pointed out by Elsey (1935, p. 153) as a factor favoring Pacific oyster growth.

The growth advantages of larger oysters of the *Crassostrea* type over small oysters are reflected in the displacement of the European oyster, *O. edulis,* by the Portuguese oyster, *C. angulata,* along the shores of western Europe, and the rise of the introduced Pacific oyster to a dominant position on the Pacific coast of the United States and Canada.

The large Pacific oyster (Figure 5) reaches marketable size of 6 to 7 inches (valve length) in 2 to 3 years on the California coast. Eastern oysters in San Francisco Bay formerly were harvested when about 4 years old and 3½ to 4 inches long (Townsend, 1893, p. 357). Native oysters reach marketable size in 3 to 5 years in California but are only about 1½ to 2 inches long. Hopkins (1937, p. 441) provides another comparison of size, stating that 1 gallon of marketable oyster meat requires 50 to 200 Pacific oysters, 150 to 250 eastern oysters, or 1,600 native oysters.

The larger oysters, such as the easterns and Pacifics, have a further advantage over native oysters in their greater rates of reproduction. Although these larger oysters do not reproduce in California waters, their occurrence in large numbers elsewhere has made possible their importation on a large scale to support the California industry. During the spawning season, chiefly June and July, the eastern and Pacific females, "discharge in one shedding tens of millions of eggs and repeat the process several times during one spawning period" (Galtsoff, 1956, p. 412). Only a small part of the eggs spawned are fertilized by sperm which the males have discharged into the water, and the number of

larvae which survive the hazards of 2 or 3 weeks in the water before they set is smaller still (Korringa, 1952, p. 296). Despite very high losses, the great numbers of eggs produced enable eastern and Pacific oysters to maintain fairly high reproduction rates.

FIGURE 5. Species of oysters grown in California. Left, Pacific oyster; center, eastern oyster; upper right, native oyster; lower right, Kumamoto oyster. *California Department of Fish and Game photograph.*

The reproductive process and size of *O. lurida* tend to limit its reproductive powers. This oyster is viviparous, the females holding the developing embryos in their bodies for about 10 days. Only the males eject their sex products into the water. As the females filter the sperm-laden water, the sperm enter the branchial chamber where fertilization occurs. The developing young are held in the branchial chamber for about 10 to 14 days (Hopkins, 1937, p. 500; Elsey, 1935, p. 131), while they develop their valves. These larvae are then released into the water, where they are free-swimming and develop further for about 30 to 40 days (Hopkins, 1937, p. 500) until they settle to the bottom and become sedentary.

This process aims to insure maximum egg fertilization and protection of the very young larvae, but the fewer eggs produced by the female and the small size of its body greatly limit the number of native oysters that can be produced. Furthermore, the larvae, typically 250,000 to 300,000 per brood (Hopkins, 1937, p. 459), are subject to the hazards of a free-swimming existence for at least twice as long as *C. virginica* and *C. gigas* larvae with only the slight advantage of having already developed thin, protective valves.

Ecology of California Oyster Growing Areas

Water Temperature

The tolerance range to various ecological conditions of exotic oyster species imported into California is great enough to permit them to grow but not to reproduce. Water temperature is one of the most important environmental factors affecting the functioning of oysters. Although water temperatures along the California coast do not reach the seasonal extremes experienced by the imported species in their native habitats, our cool summer waters, resulting from upwelling, generally inhibit spawning and larval development.

Native oysters spawn at minimum temperatures of about 57° to 61° F. (Hopkins, 1937, p. 460), whereas eastern oysters require minimum temperatures of 66° to 69° F. (Galtsoff, 1938, p. 305), and Pacific oysters, 72° to 75° F. (Elsey, 1933, p. 27). Spawning may occur at these minimum temperatures if other conditions are favorable. For instance, Elsey (1933, p. 27) writes that Pacific females will spawn at 75° F. without the stimulation of sperm in the water if the eggs are thoroughly ripe and water temperatures have not been below 68° F. for several hours previously. It is the minimum temperature that is of critical importance, and also the length of time that favorable temperatures prevail.

Limited water temperature data (Tables 3 and 4) indicate that during the summer, the average daily minimum water temperatures in California oyster growing areas are not as high as those required for spawning of the eastern and Pacific oysters. On occasional days, the maximum temperature reaches these levels for short periods, and there is limited spawning. Townsend (1893, pp. 351-353) reported that in the late 19th century eastern oysters reproduced in San Francisco Bay to a limited extent. Present California oyster growers report some spawning among their Pacific oysters, but the larvae do not survive. Whether they perish because of temperature, salinity, or lack of food is unknown.

TABLE 3

Water Temperature Data (°F.) in California Oyster Growing Areas

Month and Number of Observations	*High*		*Low*	
	Mean	*Range*	*Mean*	*Range*
HUMBOLDT BAY (Arcata Bay), 1958				
January (29)	52.4	51.0-54.5	50.9	49.0-52.5
February (28)	53.5	52.0-55.0	51.9	49.0-54.0
March (25)	50.5	50.5-57.5	50.0	47.0-53.0
April (30)	59.1	50.0-64.0	52.6	46.0-56.5
May (31)	63.6	57.5-69.0	55.0	51.0-60.0
June (30)	68.2	65.0-72.0	58.8	54.0-64.0
July (31)	65.9	63.0-69.0	57.5	56.0-61.0
August (2)	63.6	61.5-66.0	58.0	58.0-58.0
September (19)	64.4	62.5-67.0	56.6	51.5-60.0
October (30)	59.8	57.0-63.5	53.7	50.0-57.0
November (24)	56.6	51.0-64.0	49.9	45.5-55.5
December (14)	54.6	50.5-56.5	48.2	46.5-50.0
MORRO BAY, 1958				
January (17)	56.1	53.0-59.0	50.5	45.0-51.0
February (25)	58.0	54.0-64.5	52.3	43.0-56.5
March (20)	64.6	63.5-66.0	55.2	53.0-56.5
April (19)	65.8	62.0-71.5	53.3	48.5-55.5

TABLE 3—Continued

Water Temperature Data (°F.) in California Oyster Growing Areas

MORRO BAY, 1958—Continued				
May (9)	65.3	62.0-72.0	52.1	50.0-55.0
June	n.a.	n.a.	n.a.	n.a.
July, 1944 (19)	68.6	66.2-72.5	60.3	54.5-66.2
August (30)	67.1	64.0-69.5	59.1	56.0-61.5
September (30)	67.6	66.0-70.0	60.0	55.5-63.5
October (31)	63.9	53.0-68.5	55.2	53.0-59.0
November (20)	60.6	53.0-66.0	55.2	53.0-59.0
December (30)	59.5	57.5-62.0	55.7	54.0-57.5
DRAKES ESTERO, (Creamery Bay), 1947				
July (16)	75.8	71.6-80.6	57.5	51.8-61.7
August (20)	72.8	65.3-82.4	59.5	51.8-64.4
TOMALES BAY (Nick's Cove), 1958-1959				
March 1959 (17)	61.0	57.0-63.0	55.4	53.5-57.5
April (29)	64.0	61.0-69.0	58.6	56.5-60.5
May (20)	65.5	63.0-69.5	58.3	55.5-61.0
June (15)	66.5	63.5-71.0	60.3	57.0-63.5
July (31)	66.8	63.5-72.0	62.3	59.0-65.5
August (31)	66.9	64.0-69.5	63.7	61.5-66.0
September (30)	66.0	63.0-70.5	62.3	60.0-64.0
October (31)	62.0	58.5-63.0	59.8	56.0-61.0
November, 1958 (31)	58.4	52.0-66.0	56.0	50.0-62.0
December, 1958 (13)	62.0	57.0-67.5	60.0	55.0-65.5
ELKHORN SLOUGH, 1934				
May (13)	76.3	72.5-78.8	57.9	55.4-62.4
June (17)	74.3	68.0-80.6	60.2	57.2-62.6
July (14)	78.2	68.0-82.4	61.8	59.0-67.1
August (15)	77.9	69.8-82.4	63.0	59.9-64.4

Source: Calif. Dept. Fish and Game.

TABLE 4

Water Temperature Data (°F.) San Francisco Bay (Dumbarton Pt.)

Date 1890	*Mean High Tide Temp.*	*Mean Low Tide Temp.*	*Range*
July 12 to 19	69.6	71.9	67-73
July 20 to 29	70.9	71.9	69-74
July 30 to August 8	69.5	69.7	68-72
August 9 to 18	70.3	70.7	68-72
August 19 to 28	71.4	72.0	69-74
August 29 to Sept. 7	70.0	69.1	67-72
Sept. 8 to 17	67.8	68.0	64-71
Sept. 18 to 27	66.1	67.3	64-70
Sept. 28 to Oct. 7	65.6	62.9	58.70
Oct. 8 to 12	63.2	64.0	62.65

Source: Townsend, 1893, p. 348.

Although reproduction among imported oysters has been generally unsuccessful, the fact that spawning does occur means many of them are not in marketable condition for all or part of the summer. As the oyster's sex products form, they utilize stored glycogen, a carbohydrate substance that makes oyster meat plump and solid. After spawning, oysters are thin and watery and remain emaciated until sometime in the fall when they begin to recover by accumulating glycogen. The timing of recovery is related to the food supply and water temperature. Usually oysters begin to reach marketable condition in early fall. As a result, the operations of the California oyster companies are much reduced during the summer.

Functioning of the organs that affect feeding is largely controlled by water temperature. The gills of eastern and Pacific oysters pump most effectively when water temperatures measure from 63° to 82° F., with the higher temperature optimum (Loosanoff and Nomijko, 1946, p 261; Hopkins, 1935, p. 195). According to Hopkins (1933, p. 483), the optimum temperature for functioning of the Pacific oyster's adductor muscle and mantle is somewhat lower than the optimum for the gills. He puts the optimum temperature for oyster feeding at 68° F. The water temperature in California bays is usually not this high (Tables 3 and 4), but usually are within the oyster's range of adaptability. Hopkins (1931, p. 14) describes an optimum feeding temperature for native oysters of about 63° F.

During winter when water temperatures drop below 43° F. eastern oysters cease feeding (Galtsoff, 1936, p. 245) and hibernate in their native habitat on the northern and middle Atlantic coast. In California coastal waters, winter water temperatures do not drop so low and transplanted eastern oysters, able to feed throughout the year, attained marketable size at least 12 months earlier than in their native habitat. According to Elsey (1933, p. 4124) Pacific oysters can feed actively at temperatures as low as 38° F. Native oysters cease feeding at about the same temperature as eastern oysters, 43° F.

Salinity

Oysters tolerate a wide salinity range (Loosanoff, 1952; Hopkins, 1936; Amemiya, 1926, 1928). According to Galtsoff (1936, p. 246) oysters thrive equally well in water containing 10 parts per thousand or 27 parts per thousand of salts, and survive for a time in water of higher or lesser salinity.

Salinity of California waters is considered favorable for oyster growth. California growers say that after a period of rain which reduces the salinity over their shallow beds, oysters puff up because they have absorbed this less dense water, but they return to normal after a short time.

Bottom Conditions

Oysters are planted on tidal flats composed of mud or mud and sand. In general, areas with soft, deep-mud bottoms where the water is little disturbed by tidal currents or water movement are used as seed beds. Areas with firm, sandy bottoms where stronger currents bring fresh supplies of food-bearing water are used as fattening beds.

Soft, deep-mud bottoms that are generally not subject to shifting by forces of storms and floods are good seed bedding grounds because the light shell on which the seed is set ordinarily does not sink into it. However the slight tidal currents in such areas make them poor feeding grounds, and the oysters are transplanted to fattening grounds after about 12 to 18 months. The larger oysters, by virtue of their greater weight, anchor in the mud or sand and avoid shifting about and burial by tidal currents.

Within a growing area, there is usually a wide range of bottom conditions, including medium-firm bottoms where oysters can be raised from seed to maturity without transplanting. Oyster growers exploit the firmer bottoms first because they produce marketable oysters; how-

ever as these bottoms are usually more limited in extent than softer bottoms, it is usually necessary to develop the soft bottoms by utilizing them as seed beds.

Tides

The two high tides and two low tides experienced each day along the California coast are each of unequal magnitude, and the lower of the low tides often exposes most of the tidelands where the oysters are grown. While the daily tidal range between mean higher high tide and mean lower low tide is not great, being about 5 feet on the average (United States Coast and Geodetic Survey, 1960), the shallowness of the bays allows large areas of their bottoms to be exposed at lower low tide. This can be a help or hindrance to oystermen as will be discussed later.

During times of spring tides, more tidelands are exposed than otherwise. Depending on the height of the ground on which they are located, beds may be exposed daily on the lower low tide, or less frequently, perhaps only on some of the more extreme of the monthly spring tides. To oystermen who work their beds during exposure periods, it is important to know the timing and duration of the lower low tides. Those oystermen who work the beds when they are under water can work both high tides and thus their operations are less restricted by tidal fluctuations.

Weather

Storms are the most important meteorological phenomena that affect oyster growing. The most severe storms occur in winter and come from the southwest and southeast. They can easily affect the shallow beds, causing oysters to be piled up or washed up onto the shore, requiring rescattering. Serious losses can be incurred when storms cause the bottom mud to shift and smother the oysters. Floods can also cause silting. In northern and central San Francisco Bay, silting from flood waters of the Sacramento and San Joaquin Rivers sometimes has caused large losses of shellfish.

Pests

California waters are, in general, free of serious oyster pests. The bat stingray is potentially very destructive and has had an important effect on oyster culture. By locating their beds on the tidal flats where they could be fenced, oyster growers have largely eliminated bat stingray depredations.

The rays enter protected bays in large numbers in early spring to bear their young, and they remain until fall. The adults are large, commonly 3 to 4 feet wide, and they weigh as much as 150 pounds or more. A ray can destroy several acres of oysters within a short time. Townsend (1893, p. 348) describes them as having heavy, flat teeth arranged in a sort of pavement in each jaw. With these teeth they crush the oyster shells and devour the meats. Oystermen have found that rays do not bother adult Pacific oysters, possibly because they cannot crush the heavier shells, and therefore the fattening beds are not fenced.

At present oyster growers, with the permission of the Fish and Game Commission, are attempting to destroy the rays. At Morro Bay

the growers fish for them. At Humboldt Bay they drag the bottom with trawl nets and have also set traps consisting of small enclosed areas between fenced beds. A company at Humboldt Bay caught and sent to a local fertilizer plant about 45,000 rays between 1955 and 1960. They have also tagged some, hoping to learn details of their migratory habits. If the same colonies of rays are shown to return to the same bays each year, it may be possible eventually to eradicate this menace and the trouble and expense of keeping up the fences.

Crabs are not pests in all of the growing areas, but rock crabs, *Cancer antennarius* and red crabs, *C. productus,* are pests in Humboldt Bay, and the local oyster company sets traps for them in the spring. Red crabs are described as the worst oyster pest on Tomales Bay beds, particularly in August and September. The rock crab is a minor pest in Drakes Estero.

Eastern drills, *Urosalpinx cinerea,* were accidentally introduced into San Francisco Bay and Tomales Bay with early shipments of eastern oyster seed. They became numerous on the Dumbarton and Belmont beds in south San Francisco Bay where oystermen tried to starve them out by not planting areas where they were particularly numerous. This drill is still a pest on the Millerton Point beds in Tomales Bay. Department of Fish and Game inspection has kept Japanese drills out of California waters, except for a minor infestation of the Millerton Point beds in Tomales Bay.

Morro Bay waters become choked with a green filamentous alga, *Enteromorpha* sp., during the summer. The large numbers of this plant inhibit oyster feeding and make working the beds difficult.

Pollution

According to Galtsoff (1956, p. 414) pollution can affect oysters in three principal ways: direct poisoning; smothering by sludge; or raising the coliform bacteria count to where there is danger of typhoid and paratyphoid infection of consumers. Domestic sewage is usually the source of the latter contamination, which does not necessarily affect the oyster itself. Industrial pollutants often contain substances that are toxic to oysters, either immediately or after continued exposure. Pollutants may, by combining with the oxygen in the water, lower the oxygen content below that necessary to sustain marine fauna.

The effects of a pollutant may be indirect. As Galtsoff (1956, p. 415) says: "Its presence in water upsets the chemical equilibrium of oyster environment to such a degree that growth of some of the micro-organisms constituting the necessary food of shellfish is suppressed while the growth of useless or even harmful forms is encouraged."

Pollution may well have been the reason the early oyster industry failed in San Francisco Bay. Beginning sometime after 1905, eastern oysters raised from imported yearling seed showed poor growth. The meats were described as thin and watery and slow-growing (Bonnot, 1935, p. 67). Exactly what new ecologic conditions in the bay so affected the oysters is not known. The descripition of the oysters indicates either they were not feeding properly, or the proper food was not available, or both. It is commonly held that pollution of some kind contributed to this situation.

A few years before the industry failed, concern had been voiced over growing domestic and industrial pollution of the bay and its effect on the oysters (*Pacific Fisherman,* March 1905, p. 17; Wilcox, 1906, p. 17). However this concern was chiefly with the danger of contaminated oysters to human health.

Sanitary investigation of San Francisco Bay waters made shortly after oystermen had given up planting eastern seed oysters indicated pollution was not serious (Kennedy, 1912; Miller *et al.,* 1928). Kennedy (1912), a public health student, tested the water in the vicinity of the oyster beds. He found some pollution near the sewer outfalls of towns along the west side of the bay, but no serious pollution of water over the oyster beds. The fact that oysters were held in the bay off South San Francisco until about 1940 indicates some parts of the bay were clean from a public health standpoint. However, the Pacific oysters planted in the 1930's did not grow well and the native oysters did not develop fully as adults (Bonnot, 1935, p. 71; 1938, p. 195).

According to Miller *et al.* (1928, p. 256), there were relatively large amounts of dissolved hydrogen sulfide in only a few places in the bay, none of them in the vicinity of the beds. In general, the chemical effect of sewage was dissipated by tides and currents. Pollution that lowered the oxygen content of bay waters, according to this study, seems not to have been the cause of the eastern oyster decline. What the changed conditions were and what caused the change remains unknown. Tests for the wide array of industrial wastes were not made.

Pollution has apparently not posed a serious threat to the California oyster industry since the early part of this century. Many of the oyster growing areas developed since then, have had little or no settlement on or near them, for example, Tomales Bay, Drakes Estero, and Elkhorn Slough. At Morro Bay the small resort town has not been a source of pollution to the oyster beds. In Humboldt Bay (Arcata Bay), however, pollution posed problems for oyster growers in the 1930's, one of several factors that contributed to abandonment of the area for some time. This problem still existed in the 1950's when oyster growing was again undertaken, but a sewage treatment plant installed by the town of Arcata in 1958 has nearly eliminated this problem. Another area developed in the 1950's, Bolinas Lagoon, is polluted by sewage from the town of Bolinas, but the seed oysters planted in this small bed are transplanted to the clean waters of Drakes Estero where they cleanse themselves in the course of their water filtering activities. A 30-day period of such cleansing is required by State Public Health regulations.

Little work has been done on the ecology of oysters in California waters, and what has been done has been concerned with *O. lurida.* Coe (1932, 1932a) did some experimental work on native oysters at La Jolla in southern California, but conditions there, particularly water temperatures, are somewhat different than those of the commercial growing areas farther north. Bonnot (1937a) attempted to collect data that would help relate environmental conditions in Humboldt Bay to native oyster growth, but his efforts were limited, and he relied on the work of Hopkins (1937) in Washington. No work on the ecology of the eastern and Pacific oysters has been done in California. Studies have been made of some aspects of the physical and chemical conditions

of San Francisco Bay (Sumner *et al.*, 1914; Miller, 1928) and Humboldt Bay (Washington State, 1955), and a general ecologic study of Elkhorn Slough has been made (MacGinitie, 1935), but these studies cannot be specifically related to oyster ecology. Little is known of ecologic conditions in Morro Bay, Drakes Estero, Bolinas Lagoon, and Tomales Bay. The observations of oystermen in the various growing areas have been the source of much of my information relating to oyster ecology.

THE SAN FRANCISCO TRADE IN SHOALWATER BAY OYSTERS, 1850-1869

The California oyster industry was built on the demand for a familiar and favored food by many of the easterners who poured into the State following the discovery of gold. Commercial oyster production had long been established in the eastern seaboard states, where it was the most important fishery. In 1880, for example, the first year for which fishery statistics are available, the total value of all United States fishery products was $43 million with the oyster fishery contributing $13 million (Goode, 1887, Sec. II, p. vi). In earlier years the contribution of the oyster to the total fishery was probably at least comparable.

Oysters were plentiful, cheap, and widely consumed in the eastern states. An indication of their importance is found in the report of P. de Broca (1876, pp. 271-319), who had been sent to study the United States oyster industry by the French government in 1862. He wrote in part: "This delicious article of food has become so necessary with every class of the population that scarcely a town in the whole country can be found without its regular supply. By means of railroads and water channels, oysters in the shell, or out of the shell, preserved in ice, in pickle, or canned, are carried even to the remotest parts of the United States. The cities of Fair Haven, Boston, and Baltimore are at the head of the western commerce for transportation into the interior. . . . Canned and pickled oysters go . . . to California, Australia, the Antilles, and to a few markets in Europe."

In advocating American oysters for France, de Broca (1876, p. 284) said: "But it will be necessary to bring the price of the oyster within the limits of every purse, as is the case in the United States, where it is considered one of the most common and cheap means of subsistence."

Oysters from the east coast were shipped to California at least as early as 1849. The earliest issues of the *Alta California*, a San Francisco newspaper, carried advertisements for eastern oysters. On December 15, 1849, it contained a notice of the cargo sale of the ship *Oxnard* that included "Baltimore oysters." Probably these were canned oysters, Baltimore being a well-known oyster canning center at that time (Smith, 1913, p. 258). Notices of oyster sales continued to appear in the *Alta California*. Most of the oysters were from Baltimore, but some were shipped from Boston. Often they were advertised simply as "oysters," but sometimes they were described as "tinned," "spiced," or "fresh." However, the latter were seldom in good condition when they arrived in California. The *San Francisco Alta*, (December 20,

1866) noted that, "oysters have frequently been shipped across the Isthmus, but they always died before reaching our coast."

The small amounts of preserved oysters received from the east coast and the failure of fresh oyster shipments left unfilled a large California demand, particularly in San Francisco, the chief port and largest population center.

Native oysters, with their small size, rather dark meat, and strong, coppery flavor, did not appeal to easterners accustomed to the larger, whiter, and milder oysters. But some use was made of local oysters; the *San Francisco Times* (September 19, 1859) reported oysters were principally brought from Shoalwater Bay, Washington, and Tomales Bay, California. This appears to be the only reference to use of native oysters from Tomales Bay, and the native oysters found near San Francisco were probably of minor importance compared with those of the same species from Shoalwater Bay, which were larger and milder.

Oyster Importation

Native oysters were first brought from Shoalwater Bay to San Francisco in 1850 by a Capt. Feltstead (Hittell, 1882, p. 362). Hittell states that the oysters died en route, but the experiment was repeated successfully the following year by Anthony Ludlum. The *San Francisco Alta* (November 23, 1851) announced arrival of a sample shipment of 600 bushels of oysters brought by Capt. A. Miller from Puget Sound.

Although the natural oyster beds of other Pacific Northwest bays were exploited for the San Francisco market, the fact that Shoalwater Bay (now Willapa Bay) was the principal source of fresh oysters for California in the 1850's and the 1860's caused the business to be known as the Shoalwater Bay trade. After serious flooding of the Sacramento-San Joaquin Rivers in the winter of 1861-1862 destroyed almost all the oysters in San Francisco Bay (*San Francisco Bulletin*, March 22, 1879; Ingersoll, 1881, p. 201), oystermen sought additional sources in Natard's (Netarts) Bay, a small lagoon on the Oregon coast about 70 miles south of the Columbia River mouth; in Yaquina Bay, about 65 miles farther south; and in Puget Sound around Olympia (Hittell, 1882, p. 352). Shoalwater Bay nevertheless supplied about 90 percent of the oysters received in San Francisco at that time, with the small remainder coming from Yaquina Bay, Netarts Bay, Puget Sound, and Mazatlan on the west coast of Mexico (*San Francisco Alta,* December 20, 1866).

The Mazatlan oysters were the "largest and best," but they were seldom available. Several attempts were made to establish a trade in Mexican oysters. The *San Francisco Alta,* (April 21, 1869) stated: "In addition to oysters brought from Oregon, Shoalwater Bay and the beds planted in various parts of San Francisco Bay, may be mentioned the enterprise of bringing these favorite bivalves from the coast of Mexico. Enough of these have now been received here to familiarize our citizens with them; but the company which has been incorporated here to import them by every steamer arriving from Mexico expects soon to be able to fully supply the demand." This enterprise was no more successful than other attempts to import oysters from the Gulf of California. Ingersoll (1881, p. 204) quotes a lengthy article from the *San Francisco Bulletin* describing attempts to import Mexican oysters dat-

ing back to 1850. Although steamers were running fairly regularly between the Gulf of California and San Francisco in the 1860's and a steamer could reach San Francisco from Mazatlan in about 13 days, considerable time elapsed between gathering the oysters and their shipment from Mazatlan. During shipment the oysters were subject to high air temperatures, and ice was not available. Sometimes they were wet down with sea water, but it too was warm and did not keep them from spoiling. For these reasons and the difficulty of procuring oysters in the unsettled revolutionary conditions in Mexico, the trade in Mexican oysters did not develop beyond a few isolated shipments.

Organization of the Industry

Oysters were brought from Washington in sailing vessels that took about 6 days to reach San Francisco (*San Francisco Times,* September 19, 1859). The trade was so large that several ships were engaged exclusively in carrying oysters. There was no packing industry in Washington and all of the oysters were shipped in the shell in 100-pound sacks, or in baskets holding about 32 pounds. Some of the oysters were collected from extensive natural beds in Washington by Indians who then sold them to Americans engaged in the business. Others were collected under the direction of Americans who organized the collecting to insure a steady supply. They tonged oysters from permanent bay channels and transplanted them to prepared beds on higher tidal flats where they were readily available (*Overland Monthly,* June 1894; Ingersoll, 1881, p. 201).

On arrival from Washington, some oysters went immediately into wholesale and retail markets, but the remainder of the cargo, usually consisting of 2,000 to 5,000 baskets, was laid out on beds in San Francisco Bay where the oysters remained fresh until needed in the market.

The *San Francisco Times* (September 19, 1859) mentioned three San Francisco firms that were engaged in importing Shoalwater Bay oysters. One of these was owned by Ludlum, the pioneer shipper, who had remained in the oyster business. At that time, he had four vessels in the oyster trade, but whether he was a carrier, a procurer, or an importer is not clear.

In 1860 two men formed a partnership to work both ends of the Shoalwater Bay trade. Thomas Crellin, who ran a store at Shoalwater Bay and who had entered the oyster shipping business in 1853, procured and shipped them to San Francisco. J. S. Morgan, an oysterman and ship's captain from the east coast, set up a business in San Francisco to receive the oysters, bed them in the bay, and sell them. Morgan had come to San Francisco in 1849. After an unsuccessful try in the goldfields followed by failure to find oysters in San Francisco Bay worth exploiting, he had gone to Washington in 1851 and entered the oyster business. After returning to San Francisco, he established a company that dominated the oyster industry there for many years (*San Francisco Chronicle,* February 6, 1898; Hoover and Rensch, 1948, p. 321).

M. B. Moraghan, whose firm became important in the San Francisco oyster business, entered the Shoalwater Bay trade in 1868, only a short time before the era of fresh eastern oysters (*San Francisco Chronicle,* February 6, 1898).

Location of the Beds

The principal oyster beds lay along the Oakland-Alameda shore and along the Marin County bayshore (Figure 6). On the east bay shore, there were beds near Oakland and Alameda and farther north at Point

FIGURE 6. San Francisco Bay oyster beds.

Isabel and Brooks (Sheep) Island. In Marin County, they were near Sausalito and Point San Quentin (Townsend, 1893, p. 354).

All the oyster beds were in this central part of the bay for at least 20 years despite disadvantages that later forced their removal to the more protected southern arm. The annual flooding of the Sacramento and San Joaquin Rivers brought down through Carquinez Straits great quantities of cold, fresh water and silt. Every year some oysters were destroyed (Townsend, 1893, p. 354), and in some years, as in the winter of 1861-1862, nearly all of them were killed. The silt load carried by these rivers and deposited in San Francisco Bay was greatly increased by hydraulic mining in the Sierra foothills from about the late 1850's to the 1880's (Gilbert, 1917, pp. 11-12), compounding the difficulties of the oystermen.

Despite losses incurred at these sites, they probably were the best ones in the bay at that time, being most easily reached from San Francisco and lacking the disadvantages of San Pablo Bay and south San Francisco Bay. In the exposed San Pablo Bay, silting and storms were worse than in the central part of the bay. In south San Francisco Bay, there were extensive marshlands along the shores. These marshlands made the tidelands difficult to reach from shore, and the distance from shore also made the beds vulnerable to thieving. In addition, tidelands were largely overgrown and required clearing before they could be used. The greater distance to market was a further drawback.

Later oystermen found it expedient to bed their more expensive eastern oysters in places where they were protected from storms and silting, but in the early period of Shoalwater Bay Oysters, the oystermen apparently thought the losses they suffered were less than the trouble and expense involved in setting up beds in the southern part of the bay.

A letter describing the Alameda beds, written by a person who had traveled on San Francisco Bay, was printed in the *Sacramento Daily Union* (October 14, 1859). It read: "In my voyage homeward bound, I noticed the oyster corrals lying along the Alameda shores of the bay and contiguous to the mouths of the creeks. Here the oyster cultivators who import large quantities of the popular bivalve from Oregon, plant them in beds until the "critters" are fat enough to kill. The corral is formed of stakes and brush driven into the grounds, sufficiently strong to keep out the finny enemies of the shellfish—the principal of which is the 'stingaree'."

These beds were probably established soon after the Washington oyster trade began in 1851, because from the beginning San Francisco oyster dealers received shipments so large as to require temporary storage facilities in the bay. Ingersoll (1881, p. 201) reports that 1,700 baskets of Washington oysters were received in San Francisco in 1851, and 21,052 baskets in 1853. At the end of the decade, imports were estimated at approximately 35,000 baskets per year (*San Francisco Times,* September 19, 1859).

If there was a season during the year when oysters were not imported from Washington, it was not mentioned; however, it is not likely that oysters were imported in the spawning season, May through October, because they are not in marketable condition at that time. Oysters

may have been available throughout the year in San Francisco from the local beds of transplanted Washington oysters. These oysters did not spawn in San Francisco Bay.

Although most of the oysters brought to California were consumed in San Francisco, some firms shipped them to Sacramento, whence they often were taken to the gold-mining camps in the Sierra foothills (*Sacramento Directory*, 1861-1862). "Hangtown Fries," a dish composed of oysters, bacon, and eggs, is supposed to have originated in Hangtown (Placerville) in the Mother Lode Country.

In this early phase of the California industry, the Shoalwater Bay trade filled the demand for fresh oysters and kept the demand alive until fresh eastern oysters became available after 1869. The early native oyster operations in San Francisco thus provided a base from which the large eastern oyster industry grew.

THE EASTERN OYSTER INDUSTRY IN CALIFORNIA, 1869-1910

With the completion of the transcontinental Central Pacific Railroad in May 1869, a new era opened for the California oyster industry, the most important in its history. It then became possible to ship fresh oysters from the east coast to California in about 3 weeks. Oystermen had anticipated this opportunity, and oyster shipments were made soon after the railroad opened. The October 22, 1869, *Alta California* carried this advertisement for the first oysters shipped across the country by rail: "The first carload of Baltimore and New York oysters in shells, cans, kegs, all in splendid order, has arrived, packed and shipped by the pioneer oyster house of the west, A. Booth, Chicago, Ill."

Eastern oyster imports outstripped imports of Washington oysters within a short time, causing changes not only in the kind and source of oysters but in the method of raising them and the location of the beds in California as well.

The first eastern oysters shipped by rail to California were fully grown, but imports of seed oysters, for raising to maturity on local beds and not merely to be held for freshening, soon became more important, marking the beginning of actual oyster raising in California. However, while eastern oysters grew very well in San Francisco Bay waters, they never reproduced there, a circumstance requiring the industry to depend throughout its history on yearly importations of seed.

In the early 1870's when growers were experimenting with eastern seed oysters, it became apparent the beds previously established in the central part of San Francisco Bay were unsatisfactory. By 1875 they were all relocated in the southern bay, principally along the western shore.

San Francisco Bay remained the center of the California oyster industry because the bay was the only place in California where oystermen were able to grow eastern oysters successfully, and for many years it was the only place on the Pacific Coast where they were grown. Plantings made in other California waters, Tomales Bay and Humboldt Bay, were unsuccessful, as were early attempts to establish eastern oysters in Washington and Oregon.

Seed Oysters

Experimental shipments of eastern oyster seed were made soon after the rail connection with the east coast was established. The first car of eastern seed oysters was brought to the west coast by the Morgan Oyster Company in 1869 (*San Francisco Chronicle*, February 6, 1898).

Oystermen experimented with eastern oyster seed for several years before they were satisfied that transplanting them to California on a large-scale was profitable. The *San Francisco Chronicle* (February 6, 1898) pointed out there was a trial period of several years, extending from 1869 to 1874, before the industry was established on a sound footing, and that this required removing the beds from the central to the southern part of the bay. Ingersoll (1881, p. 202) stated it was not until 1875 that San Francisco oystermen felt justified in ordering large quantities of seed.

There were several advantages in shipping oyster seed. Losses en route of seed oysters were lower than losses of mature oysters, and loss costs were further reduced by the lower price of seed. In addition, shipping costs per oyster were lower: the transcontinental shipping price of $5 per barrel (Collins, 1892, p. 155) delivered from 4,000 to 8,000 yearling seed, many more individuals than were contained in a barrel of marketable oysters. However, the principal factor in the success of the transcontinental transplanting scheme was the ability of the eastern oyster seed to grow in California waters.

One and 2-year-old seed oysters were brought from the east coast in the spring and fall of the year, from mid-March to mid-May and from mid-October to mid-November, the two periods when they are in peak condition (Collins, 1892, p. 155; Ingersoll, 1881, p. 202). Most of these came from the bays and estuaries of New York and northern New Jersey, principally Newark Bay and the North River, but also the Raritan River, New Jersey, and Prince Bay, Staten Island. Oysters from the east side of Manhattan Island (Blue Points, East Rivers, York Bays, Staten Island Sounds, Rockaways) were preferred for flavor, but they did not survive the cross-country journey so well (Ingersoll, 1881, p. 202). The seed were packed in barrels and shipped by fast freight, taking about 3 weeks to reach San Francisco.

Most sources state that an average of 100 carloads of seed oysters were imported annually (Hittell, 1882, p. 363; Collins, 1892, p. 155; Townsend, 1893, p. 355; Wilcox, 1895, p. 206). Ingersoll (1881, p. 204) presents a table of annual seed imports for 1875 to 1880 from which the following figures have been derived (assuming 90 barrels per carload):

Year	*Carloads*
1875	167
1876	37
1877	47
1878	48
1879	14
1880	50

Except for 1875, these amounts seem low and may be the result of incomplete data.

On the other hand, figures of seed imports during 1887 to 1900 are high, especially for 1891 and 1892:

Year	*Carloads*
1887	125
1888	90
1889	81
1890	124
1891	262
1892	169
1893	129
1894	107
1895	134
1896	111
1897	69
1898	125
1899	87
1900	129

These carload figures were originally given in pounds (United States Bureau of Fisheries Report of 1900, p. 179). The conversion factor was obtained by dividing the number of carloads for 1899 (Wilcox, 1902, p. 564) into the number of pounds of seed given for that year (Bureau of Fisheries Report of 1900). Using this factor gives apparently reasonable results. The only check is Collin's (1892, p. 155) statement that the largest amount of seed received in 1 year in San Francisco between 1878 and 1888 was 120 carloads, and that receipts fell sharply in 1888.

In 1908, about 100 carloads of seed were still being received per year (*Pacific Fisherman,* November 1908, p. 35). However, imports began to decline shortly thereafter as oyster raising began to fail in San Francisco Bay. Since no further seed import figures are available, it is impossible to show the decline of the oyster raising industry in terms of seed import decreases. Probably 1910 was the last year that eastern seed oysters were imported to San Francisco Bay. In 1910 and 1911, many of the thin, watery oysters were removed to Humboldt Bay in the hope they would fatten, but this attempt to save the industry failed and probably no more eastern oysters were raised from seed in California. Fully-grown eastern oysters continued to be imported, however, and many of them were held in beds in San Francisco and Tomales Bays until sold.

Production

The volume of oysters produced in California during the latter 19th century was very substantial, climbing to 1 million pounds of meat in 1889 and reaching its highest level a decade later with 2.7 million pounds (Table 5). Production declined by about 50 percent between 1899 and 1904. There is no indication the oysters in San Francisco Bay had begun to fail at that time, but there were reports of pollution of the bay, and public fear of contaminated oysters may have been an important reason for the decline. By 1908 production had declined by about 50 percent, the principal cause being failure of the oysters.

During the period 1888 to 1908, eastern oysters accounted for about 85 percent of the oysters produced in California each year on the average (Table 6). Native oysters from Washington constituted the remainder.

Oysters were one of the most valuable fishery products in California during the latter 19th century, averaging over $500,000 annually from 1888 to 1904 (Table 5). From 1888 to 1892 they were exceeded in value

TABLE 5

California Oyster Production

Year	*Volume (pounds of meat)*	*Value (dollars)*
1888	910,000	$509,000
1889	1,023,050	571,525
1890	1,059,275	592,137
1891	1,106,910	618,455
1892	1,248,515	698,257
1895	1,145,452	539,000
1899	2,730,000	867,000
1904	1,320,291	628,023
1908	720,000	337,000
1912	476,259	280,344
1915	384,208	172,086
1925	56,925	24,394
1926	61,042	26,121
1927	55,492	23,782
1928	76,658	32,425
1929	53,020	26,509
1930	77,745	32,211
1931	129,513	75,507
1932	58,652	19,088
1933	86,461	29,171
1934	100,800	43,384
1935	106,800	40,024
1936	104,600	27,211
1937	163,300	38,417
1938	213,100	49,653
1939	245,600	51,345
1940	193,400	27,088
1941	256,100	47,754
1942	85,400	29,167
1943	117,300	37,613
1944	89,800	47,692
1945	47,900	28,386
1946	22,400	19,348
1947	24,200	25,521
1948	66,400	63,362
1949	34,700	26,398
1950	38,600	36,154
1951	43,300	45,741
1952	45,100	46,708
1953	37,600	44,309
1954	73,500	53,537
1955	218,300	88,664
1956	755,600	177,928
1957	1,359,200	286,564
1958	1,158,600	238,593
1959	1,659,699	n.a.

TABLE 6

California Oyster Production by Species

(Pounds of meat)

Year	Eastern	Pct. of Total	Native	Pct. of Total	Pacific	Pct. of Total
1888	819,000	90.0	91,000	10.0		
1889	840,000	82.1	183,050	17.9		
1890	875,000	82.6	184,275	17.4		
1891	910,000	82.2	196,910	17.8		
1892	1,020,000	81.7	228,515	18.3		
1899	2,520,000	92.3	210,000	7.7		
1904	1,019,767	77.2	300,524	22.8		
1912	472,059	99.1	4,200	0.9		
1915	375,773	97.8	8,435	2.2		
1916	197,000*	97.3	5,400*	2.7		
1917	82,000*	92.9	6,237*	7.1		
1918	136,000	95.8	6,000	4.2		
1919	152,000	91.6	14,000	8.4		
1920	112,000	92.6	9,000	7.4		
1921	77,000	98.7	1,000	1.3		
1922	74,000	100.0	---			
1923	69,000	100.0	---			
1924	52,678	100.0	---			
1925	56,900	100.0	---			
1926	61,042	100.0	---			
1927	55,492	100.0	---			
1928	72,630	94.7	4,028	5.3		
1929	43,725	82.5	9,295	17.5		
1930	72,796	93.6	4,949	6.4		
1931	53,569*	41.4	17,111*	13.2	58,833	45.4
1932	39,227	66.2	10,930	18.4	9,142	15.4
1933	58,419	67.4	1,218	1.4	26,824	31.1
1934	89,100	88.4	5,000	5.0	6,700	6.6
1935	64,000	59.9	2,800	2.6	40,000	37.5
1936	58,900	56.3	4,300	4.1	41,400	39.6
1937	67,300	41.2	5,300	3.2	90,700	55.5
1938	48,200	22.6	3,900	1.8	161,000	75.6
1939	24,100	9.8	1,600	0.7	219,900	89.5
1940	18,100	9.4	3,000	1.6	172,300	89.1
1941	18,800	7.3	1,000	0.5	236,200	92.2
1942	11,600	13.6	700	0.8	73,100	85.6
1943	11,600	9.9	3,700	3.2	102,000	87.0
1944	13,400	14.9	---		76,400	85.1
1945	9,200	19.2	---		38,700	80.8
1946	11,800	52.7	---		10,600	47.3
1947	18,700	77.3	---		5,500	22.7
1848	46,400	69.9	---		20,000	30.1
1949	6,500	18.7	---		28,200	81.3
1950	16,400	42.5	4,300	13.2	17,900	46.4
1951	25,000	57.7	2,200	5.1	16,100	37.2
1952	22,500	49.9	-		22,600	50.1
1953	18,200	48.4	---		19,400	51.6
1954	17,500	23.8	---		56,000	76.2
1955	19,700	9.0	2,400	1.1	196,200	89.9
1956	19,900	2.6	700	0.1	735,000	97.3
1957	16,900	1.2	12,200	0.9	1,330,100	97.9
1958	4,500	0.4	2,200	0.2	1,151,900	99.4
1959	996*	†	664*	†	1,658,039*	99.9

* Converted California Department of Fish and Game figures.

† Less than 0.1 percent.

only by whalebone, and from 1895 to 1904 oysters were the single most valuable fishery product.

Location of Beds

The eastern seed was first planted on or near beds already established for Washington oysters (Figure 6), but the disadvantages of these in the central part of the bay, chiefly storm and flood damage, caused oystermen to seek other sites. Townsend (1893, p. 354) mentions that beds on Oakland Creek were abandoned because of increased traffic and a sewage outfall. Oystermen could not afford losses of the more expensive eastern seed oysters such as they had been taking on Washington oysters, hence not long after the first eastern seed oysters were imported they began to move the beds to the more protected southern arm of San Francisco Bay.

The new oyster beds were concentrated chiefly along the western shore from Point San Bruno to the vicinity of Redwood City (Figure 6) at San Bruno (1872), Millbrae (1874), South Belmont (1877), Dumbarton Point (1877), San Mateo (1884), and North Belmont (1884), according to Townsend (1893, p. 357). Townsend also refers to a bed of Shoalwater Bay oysters a short distance north of Point San Bruno that was lost during a "northeaster" and thereafter abandoned. This bed may have been near Oyster Point, the only place on San Francisco Bay having a name referring to oysters. Bonnot (1935, p. 67) states that by 1875 all oyster beds were in south San Francisco Bay.

One eastern oyster bed was on the east side of the southern bay in the vicinity of Alvarado, opposite the Belmont beds. The Alvarado site was exposed to winter storms from the southwest, and for that reason was abandoned in 1890 (Bonnot, 1935, p. 67). The sites at Belmont and below Dumbarton Point, little disturbed by storms or strong currents, were found to be good bedding grounds for the newly-arrived oyster seed. From them, oysters were transplanted, after a year of growth, to Millbrae and San Mateo beds for fattening.

Oyster Companies

Information is insufficient to provide a full picture of the companies involved in the oyster business and their functions. The first shipper, A. Booth & Company, was a fishery firm that had establishments in Baltimore and Chicago and owned extensive salmon canning houses on the west coast (Ingersoll, 1881, p. 202). The Booth oyster interests were sold to the Morgan Oyster Company in 1871 (Collins, 1892, p. 154).

Some of the companies in the Shoalwater trade, such as the Morgan Oyster Company, expanded into the trade in eastern oysters, and the latter soon became the major part of their business. Morgan imported the first oyster seed from the east coast (1869) and established one of the first beds in south San Francisco Bay, near Millbrae in 1874. His was the largest of the two companies remaining in the business after 1885, and it survived the longest. After the losses suffered in the unsuccessful attempt to remove failing eastern oysters from San Francisco Bay to Humboldt Bay, the Morgan Oyster Company underwent financial reorganization and finally was sold to the Consolidated Oyster Company in 1921. Two large San Francisco fish dealers, A. Paladini, Inc., and F. E. Booth Company, Inc., were stockholders in the Con-

solidated firm *(Pacific Fisherman,* December 1932, p. 30). Morgan later sold some of his property along the San Mateo County shore, containing extensive deposits of old oyster shells, to the Pacific Cement Company of Redwood City (Hoover and Rensch, 1945, p. 321).

The other important oyster producer was M. B. Moraghan who began in the Shoalwater trade in San Francisco in 1868. He had beds of eastern oysters at Millbrae (Townsend, 1893, p. 357) and Coyote Point (Bonnot, 1935, p. 67). Townsend describes Moraghan as an importer, planter, and wholesale and retail dealer. The Moraghan Oyster Company seems to have carried on for some years after its founder died in 1898, but had difficulties after the turn of the century. A notice of reorganization appeared in the *Pacific Fisherman* (July 1915, p. 36) and read: "The Moraghan Oyster Company of San Francisco, which has limited its operations closely for some time past, is preparing to work its oyster beds on the San Mateo County bay shore. Last year the tidelands on which the company's oysters were planted were permitted to revert to the state through non-payment of taxes. The company has lately been reorganized, with H. L. McKnew, an experienced oysterman, in charge." On the same page as this notice was another announcing the incorporation of the Burlingame Oyster Company and listing H. L. McKnew as one of its organizers. Whether this company was formed to carry on the business of the old Moraghan company or was entirely separate is not known. Oysters had ceased to thrive in San Francisco Bay for some years, and these were bad times for the oyster industry; apparently neither company survived long after 1915.

E. Terry & Company was described as the largest wholesale oyster firm in San Francisco *(San Francisco Call,* April 27, 1879). The company planted seed in addition to importing marketable oysters. Hittell (1882, p. 363) lists E. Terry & Company as holding tideland oyster beds in San Francisco Bay. This is perhaps the same Terry who planted eastern oysters in Tomales Bay in 1875 (Townsend, 1893, p. 364). When and under what circumstances Terry came into the oyster business in San Francisco and what his background was are not known; he is not mentioned in any of the newspaper articles dealing with the Shoalwater trade. Probably his business was taken over by the Morgan company by 1885, the date, according to Bonnot (1935, p. 67) by which the several oyster companies had been reduced to two. Collins (1892, p. 154), writing of the late 1880's, states that the entire oyster fishery of San Francisco Bay was controlled by two firms, Morgan and Moraghan.

Hittell (1882, p. 363) mentions two other firms in his list of San Francisco oyster producers, Swanberg & West and Doane & Company. The former bought the San Bruno bed which Corville & Company had established in 1872 and worked for several years. Before that, Swanberg & West had kept both eastern and Shoalwater Bay oysters at Pinole Point (Townsend 1893, p. 353). Their business was absorbed by the Morgan Oyster Company in 1885 (Bonnot, 1935, p. 67; Townsend, 1893, p. 357).

Doane & Company was probably in the San Francisco oyster business in the early 1870's. Townsend (1893, p. 354) reports they once had Shoalwater Bay oysters a short distance north of Point San Bruno and also had beds of both eastern and Shoalwater Bay oysters off Oak-

land and Alameda. Since Bonnot claims that by 1875 all oyster beds were located in the southern part of San Francisco Bay, Doane & Company must have had the above beds before that date. The location of their beds in south San Francisco Bay is not known. As late as 1884 they established a bed at North Belmont (Townsend, 1893, p. 357), but according to Bonnot (1935, p. 67) they sold it and their business the following year to the Morgan Oyster Company, and Mr. Doane became Morgan's field superintendent.

Many other companies were formed by people who saw in the oyster industry an opportunity to establish a successful business, but for various reasons they did not last long. As Collins (1892, p. 154) states: "From time to time others have made feeble attempts to go into the business and have located beds and planted seed on a small scale. But these efforts have proved abortive and those concerned in the attempts soon sold out their interests to the pioneer firms or have abandoned the business under even less advantageous circumstances."

During the first decade of the 20th century, before the failure of the eastern oysters in San Francisco Bay, a number of small companies attempted to establish beds on the San Leandro tidal flats. It appears that these companies did not purchase or lease the land, but held it under State regulations. This tenure situation led to claim jumping and disputes over claims. The *San Francisco Call* (July 20, 1903) reporting a quarrel over oyster land rights off San Leandro, said when oyster beds were first planted, there was little effort to make them pay and many oystermen did not comply entirely with the State regulations regarding holding of oyster land.

The extent to which these quarrels were carried is brought out in a number of articles published in 1905 in the *Pacific Fisherman.* One of these (May 1905, p. 27) reported: "War has broken out again over the oyster beds of the San Leandro, Cal, water front, and so bitter is the feud between rival companies which claim the beds that shotgun guards have been employed to hold the contested claims. . . . The Darbee & Immel Oyster and Land Company (faction of the Pacific Oyster Company of San Francisco) had obtained a temporary injunction against the Smith Oyster Company of Oakland, Cal., restraining the latter from interfering with the possession of its recently constructed wharf at Robert's Landing. The fight . . . between the two rival companies has occupied the attention of the courts for the last two years, and has frequently given concern to the peace officers of Alameda County. The wharf of the Darbee & Immel Company was recently cut down by employees of the Smith Company."

Despite this chaotic situation at least one company of the east bay, Darbee & Immel, continued to produce oysters until about 1914 (Sumner *et al.*, 1914, p. 4).

Tidelands

According to the "California method" of oyster culture the oysters were planted in beds on the flats between high and low tide levels. Tidelands could be purchased from the State until 1909. In addition, the State recognized a claim to tidelands on the basis of occupancy for the purpose of raising shellfish. Legislation passed at the time the oyster industry was established in 1851 (*Cal. Statutes,* Ch. 117, p. 432), pro-

vided that on any State owned tidelands where native oysters did not already grow: "Any person or persons who hereafter may lay down and plant oysters shall stake off the land on which the same is or hereafter may be and such stakes shall be sufficient boundaries to entitle such person or persons to the exclusive use and occupation thereof for the purpose prescribed in the act: provided that nothing therein shall be deemed to authorize any impediments or obstructions to the free navigation of the said waters as now used." The State further recognized that: "The ownership of and the exclusive right to take up and carry off the same (oysters) shall be continued and remain in such persons who shall have laid down and planted the same." The act provided for punishing persons trespassing and causing destruction on the beds, with a $100 fine for each offense and the right of the oyster planter to sue for damages.

The right to use State tidelands for growing oysters encouraged the new industry, inasmuch as oystermen did not have to invest in land, and the laws further gave them recourse against the depredations of oyster thieves and claim jumpers. Although the State could sell to someone other than the grower the land on which his beds were situated, probably most of the tideland on which Shoalwater oyster beds were maintained continued to be held under the occupancy provisions of the Oyster Act of 1851. However, the shift to eastern oysters in the 1870's required a greater investment both in the oysters and in clearing and preparing the land, and the protection afforded the oysterman under the 1851 Act became inadequate. An oyster act passed March 30, 1874 (*Cal. Statutes*, 1874, p. 940) reiterated the tenure provisions of the earlier act and further stated: "This act shall not apply to any tidelands which the State may have sold to private parties: provided further, that nothing herein shall be construed as to interfere with the right of the State to sell or dispose of any of the tidelands, nor to affect in any manner the rights of purchasers at any sale of the tidelands by the State." This provision led most oystermen to purchase the land on which they relocated their beds in south San Francisco Bay.

Various estimates have been made of the amount of tideland in San Francisco Bay held by oyster companies. Figures in the range of 2 to 3 thousand acres certainly included land leased as well as owned by the operating companies, but tell nothing of the amount of land actually used as oyster beds. The *San Francisco Bulletin* (March 22, 1879) stated that the five companies engaged in the business of importing, growing, and selling oysters had 800 acres in oyster beds, but not all of that relatively small area was in use all of the time. This total of 800 acres agrees with the acreage figures given by Hittell (1882, p. 363) a few years later: Morgan, 200 acres; Terry, 200 acres; Swamberg & West, 100 acres; Moraghan, 200 acres (last figure from Townsend, 1893, p. 360).

In 1885, with all the oyster growers except Moraghan sold out to Morgan, the two remaining companies still owned only 400 acres of tideland (Collins, 1892, p. 156), suggesting the other companies had sold their businesses to Morgan, but not their tidelands. Townsend (1893, p. 360) estimates the Morgan Oyster Company owned and leased between 1,500 and 2,000 acres of tideland and quotes the manager of this firm as saying they had nearly all the oyster land they con-

sidered suitable for their growing method. Townsend also says that Moraghan leased an additional 900 acres. Neither of these companies had oysters bedded on their total acreages, but held excess tideland for flexibility in shifting the oysters to new beds, to keep other oystermen from establishing beds near theirs, and to maintain their near monopolies.

It was possible to purchase California tidelands until March 25, 1909, when an act prohibiting their sale came into effect (*Cal. Political Code,* Pt. 3, Tit. 8, Ch. 1, Art. 2, Para. 3443a; *Cal. Statutes,* 1909, p. 774). However, by the time the act was passed, the oyster industry was on the wane and most of the land considered valuable for oyster culture had long since passed into the hands of private parties. Collins (1892, p. 156) says that according to the Land Office Register at Sacramento the available tidelands had all been purchased, both in San Francisco Bay and elsewhere along the coast and, "If any remain unsold, they are in localities not easy accessible or not well adapted to oyster beds. . . . It is believed that a considerable part of those lands have been bought purely for speculative purposes and for this reason no record can be obtained of the quantity actually purchased for oyster beds."

The scarcity of good oyster land for sale made it expensive. While the State originally sold the land for $1.25 per acre (Townsend, 1893, p. 359; Ingersoll, 1881, p. 203), $100 per acre was the going price for good oyster land toward the end of the century. Townsend (1893, p. 360) quotes Moraghan as saying that some beds, "are worth fully $1,000 per acre to us as we have been improving and working upon them for the past ten years." Townsend also mentions that the Tide Land and Water Front Company of San Francisco, "proprietors of tidelands to a considerable extent," offered for sale some of the remaining tidelands less suitable for oyster culture at $25 per acre.

Investment

The monopoly of the oyster industry achieved by Morgan and Moraghan testified not only to their business acumen, but also to the fact that success required a very substantial investment. The cost of seed and freight, on which there was no return for 2 or 3 years, was considerable, to say nothing of land and equipment investment and their maintenance. Wilcox (1898, p. 637) states, "The constant replenishing of the oyster beds by bringing seed from the Atlantic is a heavy tax on the business, the expense for seed during the past 9 years aggregating $350,000." Using conservative figures, a carload of yearling seed containing 90 barrels cost $3 per barrel or $270 (Ingersoll, 1881, p. 202; Collins, 1892, p. 155; Doane, 1904, p. 31), and $5 per barrel or $450 in freight charges (Collins, 1892, p. 155), making the total cost $720. With average annual imports of 100 carloads of seed, annual outlay for seed and freight was approximately $72,000. A small grower who received only 10 percent of the seed had to invest about $7,200, a considerable expenditure for a company capitalized at $15 to $25 thousand, as were most of the small firms that attempted to establish themselves in the business.

Various estimates have been made of the total investment of the oyster growers. Ingersoll (1881, p. 203) gives a figure of $570,000 for

all of the companies. Hittell (1882, p. 364) estimates the investment was $400,000; $300,000 in beds, and $100,000 in equipment. Two important reports on the California oyster industry (Collins, 1892, and Townsend, 1893) give no figures on investment. However, Wilcox (1895, p. 207) gives the following breakdown, presumably for the two remaining companies: vessels, $15,000; shore property, $100,000; oyster beds, $100,000; total, $215,000. Lack of information as to exactly what these figures represent and how they were arrived at, limits their va'ue merely to a general notion of the magnitude of investment in the oyster industry.

Other Producing Areas

Outside of San Francisco Bay there was no organized, commercial oyster industry of any consequence, but attempts were made to raise oysters elsewhere in California, ranging from a rather substantial enterprise at Tomales Bay to the abortive schemes attempted in some southern California bays.

Tomales Bay

The Northwestern Pacific Railroad, which skirted the eastern shore of Tomales Bay, linked it with Sausalito, whence there was good ferry service to San Francisco. Daily communication was maintained between Tomales Bay and San Francisco from 1875 to 1930, the period during which the railroad operated (Roy D. Graves, Marin County Historical Society, Inc., pers. comm.). The railroad made it possible to transport fish and shellfish taken in Tomales Bay, chiefly smelt, herring, clams, and oysters, to the San Francisco market quickly. Despite the advantage of frequent transportation to San Francisco at an early date, oyster production did not become important in Tomales Bay until the oysters began to fail in San Francisco Bay. Apparently the beds in San Francisco Bay made it unnecessary to develop less accessible Tomales Bay.

In 1875, a shipment of 17 carloads of eastern oysters was planted in Tomales Bay near Millerton Station by Terry and Weinard (Townsend, 1893, p. 365). These were held there 2 or 3 years, when they were marketed or removed to more accessible places in San Francisco Bay. The *Sonoma Democrat* (June 10, 1876) reported that, "oyster culture along Tomales Bay has become a reality, and shipments of oysters are made to San Francisco." However, this effort was short-lived, and eastern oysters were not brought to Tomales Bay again until after 1900.

In the first decade of this century, after oyster culture had begun to fail in San Francisco Bay, oystermen again turned their attention to Tomales Bay. Eli Gordon of the Pacific Coast Oyster Company established oyster beds in Tomales Bay as early as 1907 (Bonnot, 1935, p. 68), and shortly thereafter an article in the *Pacific Fisherman* (March 1911, p. 20) described the operations of this company thusly: "The Pacific Coast Oyster Company is now rapidly developing its oyster beds on Tomales Bay, where it has obtained the opening of a station called "Bivalve" on the line of the Northwestern Pacific. The company is planting about 450 acres here and has established a large plant. Seed oysters from the east are being shipped in. The company has had a small bed at this place for several years, but kept its operations a close secret. These oysters are being brought into the San

Francisco market now and are considered by the company to be very satisfactory. They say this location is free of the sources of contamination found around San Francisco Bay."

The principal San Francisco Bay oyster grower, the Morgan Oyster Company, attempted to shift operations to Humboldt Bay rather than Tomales Bay, according to Oscar Johannson, present owner of the Tomales Bay Oyster Company and manager of its beds since 1926.

The most important development at this time for the oyster industry in Tomales Bay was the establishment of the Tomales Bay Oyster Company. The *Pacific Fisherman* (June 1913, p. 31), announced the firm's incorporation by a group of San Francisco businessmen; it was capitalized at $100,000. Although the company has changed ownership several times, it has continued to operate and is now the principal oyster producer on Tomales Bay.

Before Mr. Johannson was engaged by the Tomales Bay Oyster Company it was bought by the Pacific Coast Oyster Company (the latter company had also undergone several changes of ownership), but the two companies continued to operate under separate names: the Pacific Coast Oyster Company operating a wholesale and retail oyster business in San Francisco and the Tomales Bay Oyster Company operating the beds at Millerton on Tomales Bay. The tidal flats where the beds are located were owned by the company.

Several small businesses were started on Tomales Bay. An oyster grower named Jensen established a family business with beds near Hamlet about the time the Tomales Bay Oyster Company was established; the present operator, Henry Jensen, is the grandson of the founder. The Consolidated Oyster Company started a small bed at Blakes Landing that was later abandoned.

Records of shellfish certificates issued by the State Department of Public Health show there have been many small, non-commercial oyster plantings by individuals in Tomales Bay.

Probably some eastern seed oysters were planted and raised in Tomales Bay after the turn of the century, but at an early date Tomales Bay oystermen started holding mature eastern oysters, continuing to do so to the present. Native oysters from Washington were held until 1921 and again in the early 1930's. Pacific oysters were introduced to Tomales Bay in 1928, beginning a new phase of the Tomales Bay oyster industry that is discussed in a following section.

Humboldt Bay

Only since 1955 has there been an important oyster industry in Humboldt Bay, although several attempts were made after 1896 to establish oyster beds there. Townsend visited the area in 1885 and says (1893, p. 364) that this, "large, shallow bay may be found available for oyster growing when the question of temperature has been studied." In November 1896, he supervised planting 25 barrels of eastern oysters there (United States Bureau of Fisheries, 1898, p. cv). These were 3- and 4-year-old oysters from Princes Bay and East River, New York (Bonnot, 1935, p. 68), which, it was hoped, would achieve further growth and demonstrate that Humboldt Bay was a suitable place to establish an oyster industry.

The purpose of the experiment seems to have been to encourage expansion of the industry, as the oysters had not yet begun to fail in San Francisco Bay and there was no need to find another place in California for the beds. Although the oysters were reported to be doing well in 1897 (U.S. Bur. Fish., Rept. 1898, p. cv), the following year (U.S. Bur. Fish., Rept. 1899, p. cxxvii) Humboldt Bay seemed unfavorable for oyster culture because, "the salinity of the bay water is almost as great as that of the ocean, summer temperatures are too low for spawning, and starfish and stingrays are very destructive." Nothing more was done with oysters in Humboldt Bay until the end of the first decade of the 20th century when oystermen from San Francisco, looking for a new place to bed their failing oysters, revived interest in it.

Several articles in the *Pacific Fisherman* (1910) indicate the Morgan Oyster Company was moving its oysters to Humboldt Bay. In April 1910, the *Pacific Fisherman* (p. 20) reported, "The Morgan Oyster Company of San Francisco is making extensive improvements in its oyster beds in Arcata, Cal., where it has shipped large quantities of seed oysters during the last few months."

In the same year, small beds of local native oysters were established in the northern part of Humboldt Bay between Arcata and Mad River Channels by Louis Hegburg, Ivan Berggren (Bergen?), and Olaf Thoresen (Thorsen?) (Bonnot, 1935, p. 68). Together they formed the Eureka Oyster Company which was incorporated in 1911 in San Francisco with a capital stock of $50,000 (*Pacific Fisherman*, March 1911, p. 20). Later that year they sold their interests to the Morgan Oyster Company (Bonnot, 1935, p. 68).

Local interest in the industry had been stimulated, for the *Pacific Fisherman* reported in December 1910 (p. 12), "Dr. Horel and other Arcatans are experimenting with oysters, and are planting different varieties in an endeavor to ascertain what oysters are the most adaptable to Humboldt Bay conditions." According to the same article, Elsemore and Mercer had beds covering 900 acres in the southern part of the bay, and O. Swanberg, the former San Francisco oyster grower, also had extensive holdings there. Bonnot (1935, p. 68) writes that Louis Eaton, who later joined the Consolidated Oyster Company which succeeded to the Morgan business, also planted 250,000 adult eastern oysters in south Humboldt Bay.

The flurry of activity in the Humboldt Bay oyster business did not last long. Bonnot (1935, p. 68) reports that by late 1911 the Morgan Company was taking its oysters out as fast as market conditions would allow, but still suffered a great loss. "By 1912 they had lost $90,000 on the venture and abandoned their holdings in the Bay." The reasons for the failure are unclear. There was no scientific study of bay conditions before the beds were established to determine the most suitable places to grow the oysters, nor was any study made to ascertain the reasons for the failure. Bonnot (1935, p. 68) believed the failure was due to the same unsatisfactory natural conditions that led to the failure of the 1896 planting of eastern oysters. This gave Humboldt Bay the reputation of being unsuitable, and nothing more was done there with oysters until the 1930's when the State Division of Fish and Game, in con-

junction with the United States Bureau of Fisheries attempted to stimulate an oyster industry based on native oysters.

Southern California

Except for a few early attempts to raise oysters in San Diego Bay, there was little oystering activity in southern California until the 1930's when the State Division of Fish and Game made trial plantings in a number of bays.

In the 1870's San Diego Bay had been involved in the plans of those interested in bringing Mexican oysters from the Gulf of California to supply the California fresh oyster market. Several articles in San Francisco newspapers, quoted by Ingersoll (1881, pp. 204-205), describe plans involving bedding Mexican oysters (*C. chilensis*, wrongly identified as *O. iridescens* by Townsend, 1893, p. 361, and recently designated *O. corteziensis* by Leo G. Hertlein, 1959, p. 7) in San Diego Bay for freshening before shipping them to San Francisco. This was an attempt to avoid the spoilage occurring when the oysters were shipped directly to San Francisco. These plans apparently never materialized beyond some isolated shipments. Also unsuccessful were the schemes of later promoters who planned to use San Diego Bay as a depot for Mexican oysters (*Pacific Fisherman*, April 1912, p. 22, June, 1925, p. 30).

There seems to have been only one attempt to raise eastern oysters in San Diego Bay. Townsend (1893, p. 364) says, "a quantity of eastern oysters were placed in the Bay a few years ago and remain in good condition." The *San Francisco Chronicle* (February 6, 1898, p. 1), also mentions this experiment. Apparently it was not followed up.

In 1889, Charles H. Gilbert (1891, pp. 95-97), investigated Alamitos Bay, Newport Bay, Anaheim Bay, and Los Bolsos Creek estuary in order to ascertain their value as oyster grounds.

Native oysters grew in some of the bays in southern California, but did not form the basis of a commercial industry. Wilcox (1898, p. 647) says: "Native oysters, small in size and of little value, are found in limited quantities at several places in southern California, but are gathered only at Bolsa, Orange County. Some attempt is being made to cultivate the California oysters in the waters between San Pedro and Wilmington, where they have long been known to exist in very limited quantities." He also stated that production in Orange County in 1895 was 25,740 pounds (probably including shells) valued at $772; at the same time the production in San Francisco Bay was 14,701,500 pounds (shell weight) valued at $538,725 (U.S. Bur. Fish. Rept., 1898, p. 651).

A decade later, in 1906, *Pacific Fisherman* (October 1906, p. 23) reported the native oysters in the Grand Canal at Venice, Los Angeles County, were to be exploited commercially.

Washington State

Eastern oysters were not introduced into Washington until the 1890's, much later than in California. Washington oystermen had a large, though dwindling, resource of native oysters to sustain their business. They were not served by a transcontinental railroad until 1883, another factor that may have contributed to the late introduction of eastern oysters.

In the fall of 1894, 80 barrels of seed oysters from New York were planted in Willapa Bay under the direction of the United States Bureau of Fisheries (Townsend, 1896, pp. 196-197). The good condition of the oysters after a year gave sufficient evidence of the "suitability of the region for oyster growing from imported seed," according to Townsend. He also mentions, however, that freight rates, "were so high as to be prohibitory."

Wilcox (1906, pp. 16-17) says that private parties continued to introduce eastern seed oysters, but the failure of the oyster to reproduce when mature, making necessary continued imports of seed and continued payment of high freight charges, impeded the growth of this branch of the industry. He adds, however, that, "Up to 1900 very few eastern oysters had been taken up for shipment, but during the past few years the quantity has increased and in 1904 amounted to 38,428 bushels, some being shipped as far as Los Angeles and San Francisco." Compared with California production that year of 145,681 bushels (Wilcox, 1906, p. 7), Washington production was small; some Washington beds were owned by California producers. M. B. Moraghan and J. S. Morgan had large oyster interests at Willapa Bay (Townsend, 1893, p. 368). However, eastern oyster production in Washington State was small compared with native oyster production.

By 1905, the Morgan Oyster Company was shipping eastern oyster seed to its beds in Willapa Bay (*Pacific Fisherman*, March 1905, pp. 17-18). Previous experiments with eastern oysters in Willapa Bay by the company had indicated a growth rate inferior to that in San Francisco Bay, but Morgan was planting eastern oysters there to supply the market demand for oysters grown in Willapa Bay (formerly Shoalwater Bay) rather than in San Francisco Bay. The reports of pollution in San Francisco Bay at this time and public fear of contaminated shellfish could well have been behind the shift in demand.

A few years later, when the San Francisco Bay oysters began to fail badly, Washington production of eastern oysters became relatively important. The March 1910 *Pacific Fisherman* reported unusually large shipments of eastern oysters to San Francisco from Willapa Bay, reversing a previous relation wherein the Northwest had received its entire supply of eastern oysters from the San Francisco Bay beds.

Oregon

In Oregon, the industry has always been small, concentrating on native oysters growing in Yaquina Bay, but even here attempts were made to establish eastern oysters. Wilcox (1906, p. 17) writes, "During the past ten or fifteen years several attempts have been made to introduce eastern oysters, but the few sacks planted were stolen from the beds." He reports that in the period 1902 to 1904 further plantings were made and doing well, but to what extent they were followed up is unknown. A small production of eastern oysters is noted in 1912 fishery statistics. This attempt to increase eastern oyster production in Oregon, like that in Washington, was probably in part inspired by the oyster failure in San Francisco Bay.

ROLE OF THE CALIFORNIA DEPARTMENT OF FISH AND GAME IN THE OYSTER INDUSTRY

Beginning in the 1930's, the California Department (then Division) of Fish and Game assumed a more active role in the California oyster industry than it had in the past. It became interested in reviving the industry, taking an important part in introducing Pacific oysters from Japan and attempting to develop a native oyster industry in Humboldt Bay.

Native Oysters

O. lurida occurs along the Pacific coast of North America from Sitka, Alaska, to Cape San Lucas, Baja California (Fitch, 1953, p. 38). The largest numbers have been found in waters along the Washington coast, principally in Puget Sound and Willapa Bay. Native oysters also have been found in some protected waters along the California coast. While surveying California bays and lagoons for possible oyster growing areas, Bonnot (1935, pp. 68-75) found native oysters in Humboldt Bay, Tomales Bay, San Francisco Bay, Elkhorn Slough, Alamitos Bay, Anaheim Creek, Newport Bay, Mission Bay, and San Diego Bay, the largest beds being in Humboldt Bay.

The oysters were often growing in small clusters in sloughs, clinging to whatever firm objects were available. Referring to their occurrence in Tomales Bay, Bonnot (1935, p. 71) states, "They occur in a zone having a vertical depth of about three feet, from about two feet above mean low tide to one foot below. They are able to maintain themselves only on the rocky shores where the stones to which they cling offer protection from the sting rays." In Elkhorn Slough, they attach to rocks or pilings where they can keep their valve openings above the sand or mud (MacGinitie, 1935, p. 656, 720). Bonnot (1935, p. 71) found that native oysters in San Francisco Bay extended their range up to the sloughs during periods of low rainfall. He noted that in some parts of the bay unknown factors prevent the adults from achieving full development.

Their small size, limited feeding and reproductive capacities, and intolerance of turbid water make native oysters vulnerable to changes in their habitat, particularly rapid silting. Several lines of evidence point to the likelihood that native oysters occurred in larger numbers along the California coast in pre-historic times than in historic times and that the decrease in their numbers was rapid. There is evidence in Indian shell-mounds in the San Francisco Bay area of a sudden change in numbers, native oyster shells being important constituents of the basal layers of a few large mounds but practically non-existent in the upper layers of the same mounds. These shells were important components of lower levels of shell mounds at West Berkeley, Emeryville, and two sites at San Mateo (Nelson, 1909; Gifford, 1916; Greengo, 1951). Gifford also lists Point Isabel and Alameda as important oyster shell sites. These Indian kitchen middens were begun about 3,000 or 4,000 years ago (Gifford, 1916, pp. 12-14; Nelson, pp. 345-346). Other shell deposits, particularly the most extensive ones in the southern part of the bay, also indicate an early abundance of native oysters in San Francisco Bay. Townsend (1893, p. 355) describes these deposits

as occupying the shallow waters along the western side where they formed a beach extending for about 12 miles south from San Mateo with bars reaching into the bay. Townsend also describes a deposit of native oyster shells in the bluffs along the west side of Mare Island in San Pablo Bay. Packard (1918, p. 417) provides a map of bottom samplings in which native oysters or oyster shells were found. These samplings, made as part of the biological survey of San Francisco Bay by the United States Fisheries steamer *Albatross*, were confined to the deeper waters, but show native oyster shells widely distributed from Carquinez Straits to the Golden Gate to the lower end of the bay, with most findings in the middle and lower parts of the bay.

The locations of the various oyster shell deposits indicate that at some times conditions were favorable for growth of this mollusk and at others they were not. A number of attempts have been made to explain the apparent fluctuations of molluscan species in the bay, particularly in the shell mounds. Nelson (1909, pp. 333-338) suggests that subsidence of the area and increased sedimentation created different ecological conditions that favored one species over another. Gifford (1916, p. 10) offers the opinion that changes in dominance of species at different levels in the mounds reflect, "instances of the mound-dwellers' overtaking the supply of one particular shell species and thus being forced to rely more on other species." Greengo (1951, p. 8) writes that Gifford's explanation could suffice for the minor variations or fluctuations of proportions of species in the mounds, but he cites Packard (1819, p. 224) as corroborating Nelson's theory of ecologic change, "These changes may be due to the variations in the silting up of the basin of deposition, whereby during certain periods deposition proceeded at too rapid a rate to favor abundant molluscan life."

Within more recent times, harvesting of native oysters for sale has reduced their numbers in Tomales Bay, Elkhorn Slough, Humboldt Bay, and Newport Bay. Under the guidance of the Department of Fish and Game, an attempt was made in the 1930's to increase the numbers of native oysters in Humboldt Bay for commercial exploitation. The attempt was not successful, resulting instead in the depletion of the natural beds, which since have been made State reserves.

The cooperative agreement between the California Division (Department) of Fish and Game and the U.S. Bureau of Fisheries in 1931, marked the beginning of active government interest and participation in the affairs of the California oyster industry. At that time, the oyster industry had been in the doldrums for a number of years. No oysters were raised in the State. Supplies of fresh oysters were imported directly from growing areas in the Pacific Northwest and along the Atlantic seaboard, or came from beds in San Francisco and Tomales Bays where mature eastern oysters were held briefly awaiting sale. A few native oysters were collected from natural beds in Tomales Bay from time to time. At times native oysters from Washington were held in Tomales Bay.

In the early 1920's, the Division of Fish and Game employed Harold Heath of Stanford University to investigate the possibilities of developing the oyster industry in Tomales Bay. Dr. Heath thought this could be done, but development would require further work by a full-time oyster expert. The Division applied to the U.S. Bureau of Fisheries

for such a person, but one could not be supplied at that time, and nothing more was done by the Division about the oyster industry until 1930. According to Scofield (1932, p. 64), a renewed appeal at that time resulted in the agreement mentioned above. Under the terms of the agreement, H. C. McMillin, an oyster expert from the U.S. Bureau of Fisheries who had worked with the oyster industries in Washington and Oregon, and Paul Bonnot, a biologist employed by the Division of Fish and Game, undertook to survey California coastal waters in order to determine suitable oyster culture areas. The survey revealed the limited extent of potential California oyster grounds. Although there are many small coastal embayments where streams enter the Pacific Ocean, they are unsuitable as oyster grounds not only because of their small size, but also because in summer they receive almost no fresh water and in winter are flushed out by violent freshets. Two of the largest bays, San Francisco and San Diego, had unsatisfactory sanitary conditions. Tomales Bay had the disadvantage of being heavily infested with pests such as eastern drills and the slipper shells (Crepidula sp.). Morro Bay was not rated highly because of its shifting bottom. Three areas, however, were thought to have good potential: Elkhorn Slough, Drakes Estero, and Humboldt Bay. In Elkhorn Slough and Drake Estero, experimental Pacific oyster plantings were made in 1932 in cooperation with private companies. At Humboldt Bay, where the tidelands are much more extensive, McMillin and Bonnot recommended working with local native oysters to encourage expanding their numbers by artificial culture methods used in Washington industry. By demonstrating means of increasing native oyster production, the Division of Fish and Game hoped to encourage private concerns to develop a commercial oyster industry.

The Fish and Game Commission, policy making body of the Division of Fish and Game, approved the suggestion and restricted oyster growing in Humboldt Bay to the native species. Work was begun in 1932. However, the cooperative arrangement with the U.S. Bureau of Fisheries ended in July 1933 (Bonnot, 1935, p. 65). In that depression year, the California legislature failed to appropriate funds needed to carry on the work, and the U.S. Bureau of Fisheries withdrew after McMillin resigned to participate in one of the commercial oyster companies. However, Humboldt County wished to see the industry develop and contributed a small amount of money to retain McMillin as general adviser. Bonnot carried on the Humboldt Bay project on a much reduced scale.

Legislation and Regulations

The decision of the State to increase its activities in the oyster industry and fisheries in general was implemented by legislation passed in 1933 in the form of the *Fish and Game Code* (*Cal. Statutes* 1933, ch. 73, secs. 814-822, pp. 467-470). Bonnot (1935, p. 65) writes, "The old oyster law of 1873/4 was found to be inadequate and the Legislature of 1933 passed a new law, sponsored by the Division of Fish and Game, which takes account of and deals with present day conditions."

The law made the oyster industry, for the first time, subject to supervision by a State regulatory body. Because so much of the land

used today for oyster culture is State land, the existence of a public regulatory body having the power to enforce its regulations ensures orderly tidelands administration and gives oyster growers effective guarantee of their right to use them. The laws are contained in the *Fish and Game Code,* regulations are in the *Administrative Code,* Title 14. References in this paper will be to the 1959 *Fish and Game Code* which is essentially the same as that passed in 1957 (*Cal. Statutes* 1957, ch. 456, secs. 6480-6510, pp. 1408-1412). The present law represents additions and refinements of the original 1933 *Fish and Game Code,* but the basic provisions of the early law still stand.

A major feature of the *Fish and Game Code* is its provision for allotment of State tidelands through the Fish and Game Commission. The basis for legal occupance under the 1874 law was simply registration of a claim on the public tidelands with the local county clerk, while now application must be made to the Fish and Game Commission for permission to engage in oyster culture. A map must be included with the application, having the area with the desired tidelands drawn on it. The Commission, after consulting its records of filings, and upon finding an allotment would be in the public interest, allots the area to the applicant. The allotment system does not apply to tidelands that passed into private hands before 1909.

The grant of an allotment does not confer rights beyond cultivating shellfish as regulated by the codes. The allottee must allow public access to State land for hunting and fishing. However, the allottee has the exclusive use of the allotted land for shellfish culture and the oysters on the beds are his property, the law protecting his rights by defining theft of the oysters or any wilful destruction of the beds as a misdemeanor.

The *Fish and Game Code* not only gives authority to allot State tidelands to the Fish and Game Commission but also establishes the conditions under which the allotment can be held. The 1933 *Code* (*Cal. Statutes* 1933, ch. 73, sec. 820) stated that 10 percent of the allotment must be improved each year until the entire area of the allotment is under cultivation. Failure to improve for 2 consecutive years constitutes abandonment of the unimproved portion of the allotment. Specification of the amount of improvement required to hold the allotment has been transferred to the *Administrative Code, Title 14,* permitting changes to be made by the Commission without legislative action. *Title 14.* contains the 10 percent improvement requirement described above and further defines what constitutes improvement.

No definite duration for an allotment was specified until 1957 when the *Fish and Game Code* was amended to include a section setting a 25 year term. This provision gives the Commission the right to terminate an allotment if it finds another use of the allotted tideland, for example, recreation, is more in the public interest. However, if the allottee has a large investment in his oyster beds and conducts an active business, it is very unlikely that the allotment would be terminated at the end of 25 years. The provision is not meant to inhibit industry expansion, but is rather intended to give the Commission the power to effect a change in land use when an allotment has not been abandoned. If there is no reason to change the use of the land at the end of 25 years, the person holding it has first claim to renew the allotment.

A number of changes made in the *Fish and Game Code* in 1955 indicate a change of attitude on the part of the Commission toward the use of public tidelands. Until that time, the State made no charges for using its tidelands for shellfish culture, but in 1955 a number of fees were initiated (*Cal. Statutes* 1955, ch. 1263, secs. 1-4). A fee of $50 is required for each application for an allotment. A licensing system was put into effect with a fee of $25 each year, and a yearly rental of $1 per acre of allotted water bottoms is charged. During the first 3 years the allottee pays the rental fee only on the number of acres he has planted but after that period he must pay rent on the total allotted acreage. A privilege tax of 1 cent per packed gallon of shucked shellfish harvested from an allotment is payable to the State for the privilege of using State land. If oysters are marketed in the shell, the tax is based on the equivalent yield of shucked oyster meat.

The State does not set a limit to the amount of tideland acreage an individual or company can hold under an allotment but the requirements for improving the land and the rental fees, even though the latter are not heavy, have the effect of limiting the acreage to an amount that the cultivator can profitably use. The rental fee and privilege tax, reimburses the State a little for the use of its resources.

The institution of State regulations and fees expresses a change in State policy toward the oyster industry conducted on State tidelands from one of free, unrestricted use to one which recognizes the responsibility of persons or companies using State resources for commercial purposes to reimburse the State in some measure for services supplied.

Another phase of the work of the Department of Fish and Game is provided for in *Title 14*, requiring pest inspection by members of the Department of Fish and Game of imported Pacific seed and eastern oysters destined for California waters. Oysters and oyster seed may be inspected at their source in order to avoid the loss involved in importing contaminated oysters. The companies importing the oysters or seed if they request inspection at points of origin are required to pay for the cost of the inspection, including inspectors' salaries and transportation.

The large amount of seed imported from Japan makes this inspection particularly important. The Department sends a marine biologist to Japan each year during January and February when the seed is packed. *Title 14* requires that he inspect a minimum amount of the total shipment from each geographical origin. The California inspector usually works with the inspector from Washington (State) and Japanese government inspectors in an effort to make the inspection as thorough as possible. So far the attention given to the drill problem has kept California waters free of Japanese drills, except for a bed in Tomales Bay.

Through the *Fish and Game Code* the Department of Fish and Game has the authority to regulate the use of natural oyster reefs. The fact that the State owns the natural, native oyster beds means that persons or firms wishing to stock their beds with native oysters must apply to the Department for permission to take them.

The Humboldt Bay industry, patterning itself largely after the native oyster industry in Puget Sound, depended on the natural beds for brood stock for its own artificial, diked beds. The oystermen hoped that by putting out cultching materials in the vicinity of their beds during the setting season the number of oysters would build up and

they would not continue to be dependent on the natural beds. Because practically nothing was known of the native oyster's habits in Humboldt Bay, they proceeded by trial and error. It was important, then, that the Division of Fish and Game control the use of the natural beds, because these were limited in extent. So many people were trying to establish themselves in the oyster business that the natural beds were nevertheless badly depleted.

The Department of Fish and Game did not act merely as a regulating body. It was concerned with collecting data on conditions in Humboldt Bay to help commercial growers establish beds in the most suitable places. An oyster laboratory, financed by funds from Humboldt County and the State Relief Administration and operated by the Department of Fish and Game, was set up in Eureka in 1935 (*Pacific Fisherman,* May 1935, p. 48). Much effort was spent collecting data on the setting of oyster spat in order to know when and where to put cultching materials to catch the maximum amount of spat.

The attempts to obtain a commercial set of spat gave variable results. Bonnot (1935, p. 69) writes that the 1933 set was not successful, while in 1934 a very good one was obtained. Of the 1935 season, he writes (1936, p. 287) that the cultch was not put in the water at the right time, only one company catching a set by putting its cultch in later. The 1936 set was very heavy (Bonnot, 1937, p. 163), but in 1937 the set was comparatively light (Bonnot, 1938, p. 191). The 1939 and 1940 sets were very good, but were not so heavy as that of 1936 (*Pacific Fisherman,* December 1939, p. 72; July 1940, p. 65).

Despite some successful sets of spat, native oysters were never available for marketing except on a small scale. Most were sold locally, with occasional shipments to San Francisco. This situation led many of the oyster growers to appeal to the Fish and Game Commission for permission to import eastern seed oysters. A petition was presented in 1934 (*Pacific Fisherman,* August 1934, p. 47), but the Commission felt the area should be kept for raising native oysters only. The *Fish and Game Code* gives the Commission authority to prohibit placing any type or species of oyster or oyster seed which it considers injurious to the development of the oyster industry of the State. The Commission at first declined to permit importing eastern oysters, but continued pressure from the oyster growers, who contended it was not possible to create a profitable industry based only on native oysters, finally moved the Commission to allow oyster growers to import eastern seed oysters but not the larger Pacific oysters with which, it felt, the native oyster could not compete.

The first eastern seed was planted in Humboldt Bay in November 1935 (*Pacific Fisherman,* December 1935, p. 47), and importations continued until the industry dwindled away in the early 1940's.

Although the Consolidated Oyster Company of San Francisco was interested in raising oysters in Humboldt Bay in 1931, it did not do so, leaving the oyster industry in that area to be developed by local businessmen. *Pacific Fisherman* (October 1932, p. 69) reported interest in the new industry was so keen that more than 100 persons had staked out claims in the bay. Some of the tidelands were privately owned and others were State lands which became subject to allotment in 1933.

At present the Humboldt Bay industry is in the hands of one large firm, but in the 1930's there were many small producers, most of them inexperienced in oyster growing. Most of their enterprises were short-lived.

The Eureka Oysters Growers, Ltd., formed in the spring of 1931, cultivated about 10 acres of tideland leased from Arcata. *Pacific Fisherman* (January 1932, p. 57) reports this company shipped native oysters to San Francisco where they were marketed through Consolidated Oyster Company. By 1936 this company was no longer in business.

Pacific Fisherman (February 1936, p. 46) states there were three companies and a score or more independent operators in the business. The three companies were: the Humboldt Bay Oyster Growers Association, Inc., established in 1933 and operating a 6-acre bed on land leased from the Northwestern Railroad Company in the vicinity of Brainard; the Northern California Oyster Company, organized in 1934 and raising oysters on a 6-acre bed near the mouth of Mad River Slough; and the Eureka Oyster Company, Inc., successor to the S. C. S. & H Oyster Company in 1936, operating 5 acres of beds in the Mad River Slough area. By November 1936, the Northern California Oyster Company had gone out of business (*Pacific Fisherman,* November 1936, p. 58).

The two remaining firms continued to import eastern seed, chiefly from Massachusetts, while trying to increase production of native oysters. The first eastern seed planted in the fall of 1935 was harvested in the winter of 1937-38, and some shipments were made to San Francisco. More regular shipments of eastern oysters were made in the fall and winter of 1938-39, when native oysters were not yet ready to be shipped in commercial quantities (*Pacific Fisherman*, December 1938, p. 58).

In early 1938, a wholesale fish firm, the New England Fish Company, came into the Humboldt Bay oyster business. This company, concentrating on native oysters, established 2 acres of beds in the vicinity of Bird Island, and in 1939 added 2 more acres. In the spring of 1941, they bought out the interests and properties of the Humboldt Bay Oyster Growers Association and became the only company remaining in the Humboldt Bay oyster business (*Pacific Fisherman*, May 1941, p. 79). This company gave up its oyster operations in 1943.

When the allotment system came into effect in 1933 a number of Humboldt Bay oystermen applied for allotments. Early in 1934, the Fish and Game Commission granted 19 in the northern and southern parts of the bay. However, little or nothing was done to develop them, and all were declared abandoned in November 1937.

Confidence, aroused by the heavy set of native oysters in 1936, resulted in another wave of applications in 1937. Grants were made to the New England Fish Company and to a number of individuals. Most of these were never used, but were not declared abandoned until September 1946. The allotments of the New England Fish Company were transferred to the California Native Oyster Company in February 1942, but this company apparently did nothing with them, and they came under the general abandonment proceedings of September 1946.

Despite much activity on the parts of state, county, and private groups for a period of about 10 years, the results of the attempt to

establish a commercial native oyster industry were negligible. Production statistics published by the State show how scanty the commercial harvest was (Table 7).

The limited financial resources and lack of experience in oyster raising, on the parts of most of the people who tried it, certainly contributed to the failure of the Humboldt Bay oyster industry, but probably more important was the fact that the native oyster did not lend itself to commercial development. The oysters required about 5 years to reach marketable size; the meat of the Humboldt native was considered inferior to that of the same species from Puget Sound; the Humboldt native grew proportionately more shell and less meat; the meat did not fatten well and did not reach a marketable degree of fatness until winter, making the marketing season a short one. Besides these disadvantages of quality, the numbers of native oysters were limited. The natural beds were not extensive, and attempts to increase the number of oysters above the natural increase by putting out artificial spat collectors met with only limited success.

THE PACIFIC OYSTER INDUSTRY, 1930 TO THE PRESENT

The California oyster industry is now concerned almost wholly with raising Pacific oysters from Japan. Although the present relatively large-scale production dates only from the mid-1950's, the first attempts to raise this oyster in California occurred in the early 1930's, when the Division of Fish and Game became interested in reviving the industry. The Division was largely concerned with encouraging commercial production of native oysters in Humboldt Bay, but it also experimented with Pacific oysters, which were then the principal species of the Washington oyster industry.

Introduction of the Pacific Oyster

Scientific and commercial interest in Pacific oysters began on the west coast in the 1870's. Townsend (1893, p. 360) reports that as early as 1874 Prof. George Davidson of the University of California had expressed interest in the possibility of introducing the large Pacific oyster from Japan, but nothing was done about it at that time. Its introduction to the United States occurred in Washington in the early part of this century. In 1902 and 1903, mature Pacific oysters from Japan were planted in Puget Sound, the introduction resulting from discussions between a Washington State Fish Commissioner and Prof. Mitsukari of the Imperial University, Tokyo, begun in 1899 (Galtsoff, 1932, p. 7). An earlier introduction of this oyster, in 1875, is reported by *Pacific Fisherman* (May 1938, p. 65), but apparently it was not followed up and therefore probably unknown or ignored by many later writers.

The first commercial planting of Pacific oysters was made in 1905 by Japanese growers who acquired an area of tidelands in Samish Bay. They planted mature oysters with the hope the species would, after a time, become established through natural propagation. This effort failed, but other oystermen continued to experiment with Pacific oysters in Washington. In 1916, an experimental planting of Pacific seed oysters was made in Samish Bay by a Japanese firm (*Pacific Fisherman,*

May 1916, p. 21). The successful growth of the seed, its lower purchase and transportation costs, and lower mortality during and after shipping, led to development of a Pacific oyster industry based on seed imports. After 1931 it far surpassed the native oyster industry in Washington.

In California, active interest in Pacific oysters did not arise as early as in Washington, nor was interest stimulated when the eastern oyster industry in San Francisco Bay began to fail, at a time when Pacific oysters were already being raised experimentally in Washington. Even after they had become firmly established in Washington in the 1920's, California oystermen did not experiment with them. San Francisco Bay oystermen, for example, because of the eastern oysters' failure apparently considered the bay unable to grow oysters and suitable only as a "warehouse" for keeping mature oysters fresh.

The first experimental planting of Pacific oysters in California was made by the Tomales Bay Oyster Company in 1928, with several other experimental plantings following in the early 1930's. The Division of Fish and Game was especially active in this experimental activity. However, the principal factor in delaying establishing a significant Pacific oyster industry in California was the decision to exclude Pacific oysters from Humboldt Bay, the largest California bay available for oyster culture.

In 1929, a planting of Pacific seed oysters was made in Elkhorn Slough (Bonnot, 1935, p. 72). In 1932, small quantities were planted in Drakes Estero, Bodega Lagoon, Morro Bay, Mugu Lagoon, Anaheim Creek, and Newport Bay under the auspices of the Division of Fish and Game (Bonnot, 1935, pp. 73-75). The Consolidated Oyster Company planted some Pacific seed in San Francisco Bay in 1932-1933 (*Pacific Fisherman,* July 1933, p. 39). Some of these plantings were successful, forming the beginning of the Pacific oyster industry in California. Many were repeated, and they contributed a small amount of commercial production before World War II interrupted the supply of seed, and labor became scarce.

Imports of Pacific Seed Oysters

Failure of Pacific oysters to reproduce in California waters and their irregular reproduction in Washington bays have meant the California industry must be wholly dependent on imports of seed oysters from Japan. Therefore, the arangements involved in purchasing and shipping Pacific seed oysters are a most important part of the industry.

Early seed purchases during the 1920's and 1930's were made through representatives of Japanese seed-oyster firms. The competition among these firms resulted in very low selling prices, overbuying of seed by Washington oyster producers, and overproduction of oysters. To remedy this chaotic situation, the Pacific Coast Oyster Growers Association, a cooperative trade organization of the west coast oyster industry organized in 1930 as the Pacific Coast Oyster Growers and Dealers, began purchasing seed in 1939 for its members, most of whom were Washington growers. Seed buying is now one of the principal functions of the organization.

In the post-war period, the larger west coast growers by-passed the Association, sending their own buyers to Japan to make direct pur-

chases. Since about 1951, the Coast Oyster Company has maintained its own purchasing organization in Japan to procure seed for its large operations in Washington and California. The Morro Bay oystermen get their seed through another large Washington oyster grower who sends a buyer to Japan. Therefore, among present California oyster growers, only the small operators at Tomales Bay buy their seed through the Pacific Coast Oyster Growers Association.

In Japan, raising seed oysters for transplanting to growing and fattening beds has a history of about 300 years (Cahn, 1950, p. 10). However, raising seed oysters for export is of recent origin, and the Pacific coast of the United States has always been the major export market. Seed shipments to the United States are a small but significant part of the Japanese seed oyster industry.

The Japanese seed-producing industry is centered along the shores of Matsushima Bay in Miyagi Prefecture, about 250 miles north of Tokyo (Figure 7). Recently the Urato Islands, off the coast of Miyagi Prefecture, have also become an important source of seed for export to the United States. Some small shipments of seed have been made from Kumamoto Prefecture. The oysters produced in Kumamoto Prefecture are a variety of *C. gigas,* but are smaller, rounder, and more deeply cupped than the common variety from Miyagi. California and Washington growers have made only experimental plantings of these southern oysters which are regarded as superior in both form and flavor, but less profitable than the larger, faster-growing Miyagi oysters.

Raising and packing seed oysters for export require special care to enable the seed to survive the trans-Pacific voyage, and to ensure that it will be free of harmful organisms. Oyster spat is caught on empty shells of oysters and other mollusks, which are strung on wires and suspended from rafts or racks in areas where spat-setting is known to occur (Figure 8). The strings of shells are put into the water in July when the young oysters are ready to set, keeping them above the bottom, which is habitat of harmful oyster drills. The spat that set on the shells are left until about September, at which time the strings are removed from the floats and racks and piled horizontally on low racks in the intertidal zone where the spat are exposed to the air for several hours each day during ebb tides (Figure 9). This exposure causes the young oysters, which at this stage are less than $\frac{1}{2}$-inch in diameter, to develop thick, strong shells that do not allow water to escape, thus enabling them to survive during the periods of exposure to the air. Spat not exposed to these conditions develop larger meats and thinner shells which are not water-tight and whose edges chip easily. The spat to be exported are left on the "hardening" racks until about January or February when packing for shipment begins.

The spat containing shells are removed from the wire strings, washed, sorted, inspected and packed in wooden cases. Much of this work is done in the open air by women at many small sites in the growing areas (Figures 10, 11, 12). Women who do the sorting remove drills and drill egg-cases, count the number of live spat per shell to make sure there are the minimum number required, and sort broken and unbroken shells. Most American buyers require each unbroken shell to have at least 10 live spat on it, and that each broken shell have at least 6 live

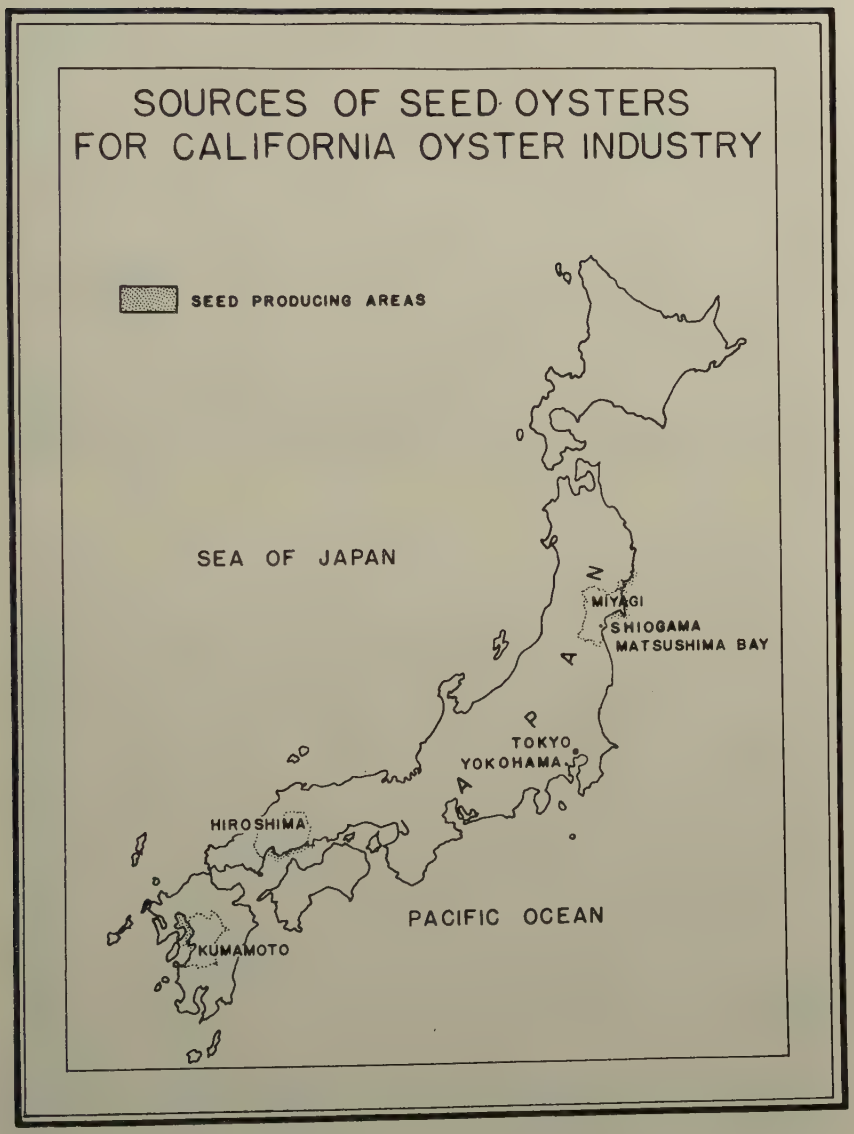

FIGURE 7. Sources of Japanese seed oysters for the California oyster industry.

FIGURE 8. Seed collection racks at Kumamoto, Japan. *California Department of Fish and Game photograph.*

FIGURE 9. Seed hardening racks at Miyagi, Japan. *California Department of Fish and Game photograph.*

FIGURE 10. Washing oyster seed at Miyagi, Japan. *California Department of Fish and Game photograph.*

FIGURE 11 Selecting oyster seed for packing at Miyagi, Japan. *California Department of Fish and Game photograph.*

FIGURE 12. Seed packing site at Kumamoto, Japan. *California Department of Fish and Game photograph.*

spat. These requirements stem from variations in intensity of spatting from place to place and from year to year. If the spat fall is light, much shell must be discarded to meet minimum requirements.

Seed buyers may purchase cases of seed on broken shell, unbroken shell, or mixed broken and unbroken shell. Unbroken shell is the cheapest and has the further advantage that it neither drifts nor sinks deeply into the muddy bottoms of California beds, but it results in large clusters which must be broken-up, a difficult and costly operation. Broken shell results in small clusters needing little or no breaking-up, but it is more expensive due to the higher spat count per case and the increased labor involved in cutting and selecting the shell. In addition, losses are greater because the small pieces of shell easily become buried in mud. Introduction of cases of mixed broken and unbroken shell in 1959 gave oyster growers a seed pack that minimized the disadvantages of each type of shell. In California, mixed shell is used on the beds in Humboldt Bay. Some California growers plant the cheaper unbroken shell, figuring that the cost of breaking up the clusters on their small beds is not greater than the additional cost of buying broken or mixed shell.

A standard wooden packing case measuring 18 by 36 by 12 inches and containing about 2 bushels of shell is the packing unit. A case of unbroken shell contains about 12 to 15 thousand spat and weighs about 110 pounds. A case of broken shells contains about 18 to 20 thousand spat and weighs about 165 pounds (Cahn, 1950, pp. 49, 51).

The packing sites are visited by personnel of various government and business groups interested in seed oyster shipments: biologists from the Japanese central and prefectural bureaus of fisheries, to insure high quality of the export product; biologists from the Washington and California fishery departments, to prevent drills and other harmful organisms from entering and infesting their waters; and buyer's representatives anxious to purchase seed that is not only clean and free of drills, but also with adequate spat counts.

Most seed oyster shipments to California are made from ports on Matsushima Bay, principally Shiogama; some shipments are made from Yokohama, depending on local availability of shipping. At some places, for example in the Urato Islands, cases are lightered to freighters anchored offshore. If the packed seed is ready more than 3 days before it can be loaded onto the ship, the cases are put upon racks in the intertidal zone to keep moist. The seed can be held safely in this manner for as long as 4 weeks (Cahn, 1950, p. 51), but importers try to arrange to have their seed shipped as soon after packing as possible in order to minimize losses due to exposure.

The cases of seed oysters travel as deck cargo. They are stacked in layers separated by $\frac{1}{2}$-inch laths to provide ventilation, covered with layers of straw matting, and roped down. They are sprayed with seawater once or twice each day to keep them cool and moist. Thus cared for, they travel for 12 to 15 days across the Pacific to California ports. Shipments are unloaded at Eureka and San Francisco.

Losses due to handling and the length of time involved in packing and shipping are considered light. However, mortality of one large shipment to Eureka in November 1955 amounted to about 80 percent and showed inadvisability of shipping at that time of year. The shipment was made in an attempt to establish a cycle of two plantings each year in spring and fall. However, several factors contributed to the low survival of fall-seed shipped and put an end to that experiment. For instance, period of exposing the spat to develop thicker and harder shells was shortened; sea and air temperatures, especially during the first 6 days of the voyage, were higher than those during the normal shipping season; and the inability to keep the oysters cool contributed further to their spoilage.

In addition, November seed packing presented drill inspection problems. High water temperatures in the intertidal zone during the summer keep drills in cooler, deeper water, but by October or November, when shallow-water temperatures are usually optimum for their reproduction, drills move into the area of the hardening racks and many get onto the strings of shell-bearing spat. The seasonal occurrence of large numbers of drills and their egg-cases, which are very difficult to discover, lessens the chances of producing drill-free shipments in November.

Shipments of Pacific seed oysters to California growers, usually made between February and March, have increased greatly since 1955 when the oyster growing operation at Humboldt Bay was initiated. Seed oyster imports from Japan since 1947 have ranged from 250 to 17,081

cases (Table 7). The unusually large figure for 1955 includes the November shipment of 9,900 cases which suffered high mortality and from which few oysters were harvested, as well as another shipment made to replace it.

TABLE 7

California Imports of Pacific Seed Oysters

Year	*Number of cases*
1947	750
1948	850
1949	350
1950	565
1951	350
1952	250
1953	250
1954	2,526
1955	17,081
1956	9,500
1957	11,915
1958	14,139
1959	12,460
1960	11,137

Seed purchases represent a considerable investment. In the spring of 1960, the cost of a case of unbroken shell, purchased by the Pacific Coast Oyster Growers Association and delivered to San Francisco, was $9.25. Mixed shell delivered at the wharf in Eureka cost $12.50 per case. These prices included shipping, insurance, and inspection costs. The Eureka shipment was in excess of 7,000 cases, representing an investment of more than $80,000.

Small amounts of Pacific seed oysters produced in Willapa Bay, Washington, have been planted in California in recent years. In the fall of 1957, 5,634 cases were carried by truck to Humboldt Bay. The following year 1,600 cases of Willapa seed were planted in Humboldt Bay. In 1959 200 cases were planted in Morro Bay and a similar amount in Tomales Bay. No Washington seed was available in 1960. The occurrence of a commercial set in Washington is quite irregular and the quantity available is insufficient for the needs of the entire Pacific coast industry.

Pacific Oyster Growing Areas

Tomales Bay

Tomales Bay has the longest record of Pacific oyster production of any California area, but its small area of tidelands has limited its production. It is the smallest of the present oyster producing areas (Table 8).

The bay is a long, narrow body of water occupying part of the northwest-southeast trending depression of the San Andreas rift valley. Hills rise steeply from both sides of the bay to heights of several hundred feet, and their slopes continue below the surface of the water, leaving only limited tidelands at the head of the bay where Lagunitas Creek enters and near the lower end on the east side where Walker Creek enters (Figure 13). Oyster beds have been established on parts of these small tidelands. The largest area currently used, in the cove at Millerton Point, covers about 28 acres.

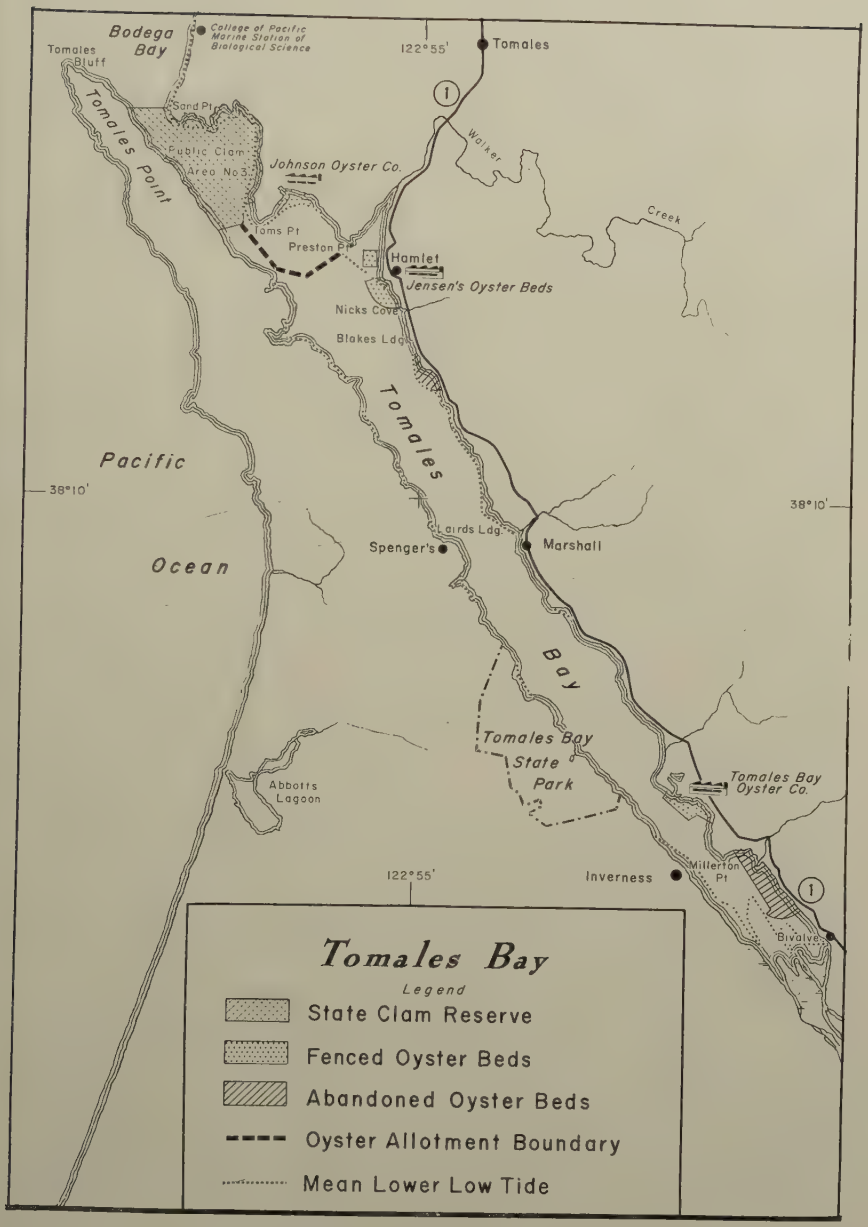

FIGURE 13. Tomales Bay, California.

The tidelands consist of soft mud, the silt accumulation carried in by the two permanent streams, Lagunitas and Walker Creeks, and numerous, small, rainy-season ones. In some places the bottom is made firm by sand, as in the northernmost part of the Millerton Point beds. The oystermen use this firm ground to bed their expensive eastern oysters.

TABLE 8

California Oyster Production by Area

Year	San Francisco Bay		Tomales Bay		Drakes Estero		Humboldt Bay		Morro Bay		Elkhorn Slough	
	(Pounds of meat)	Percent	(Pounds of meat)	Percent	(Pounds of meat)	Percent	(Pounds of meat)	Percent	(Pounds of meat)	Percent	(Pounds of meat)	Percent
1888	910,000	100.0	----	----	----	----	----	----	----	----	----	----
1889	1,023,050	100.0	----	----	----	----	----	----	----	----	----	----
1890	1,059,275	100.0	----	----	----	----	----	----	----	----	----	----
1891	1,106,910	100.0	----	----	----	----	----	----	----	----	----	----
1892	1,248,515	100.0	----	----	----	----	----	----	----	----	----	----
1895	1,145,452	100.0	----	----	----	----	----	----	----	----	----	----
1899	2,730,000	100.0	----	----	----	----	----	----	----	----	----	----
1904	1,320,291	100.0	----	----	----	----	----	----	----	----	----	----
1908	720,000	100.0	----	----	----	----	----	----	----	----	----	----
1912	*476,259	100.0	----	----	----	----	----	----	----	----	----	----
1915	360,892	93.9	23,275	6.1	----	----	----	----	----	----	----	----
1916	199,049	98.3	3,351	1.7	----	----	----	----	----	----	----	----
1917	84,002	95.2	4,235	4.8	----	----	----	----	----	----	----	----
1918	116,298	81.9	25,702	18.1	----	----	----	----	----	----	----	----
1919	125,994	75.9	40,006	24.1	----	----	----	----	----	----	----	----
1920	93,412	77.2	27,588	22.8	----	----	----	----	----	----	----	----
1921	17,394	22.3	60,606	77.7	----	----	----	----	----	----	----	----
1922	----	----	†74,000	100.0	----	----	----	----	----	----	----	----
1923	23,736	34.4	45,264	65.6	----	----	----	----	----	----	----	----
1924	20,352	38.4	32,648	61.6	----	----	----	----	----	----	----	----
1925	51,859	91.1	5,066	8.9	----	----	----	----	----	----	----	----
1926	58,478	95.8	2,564	4.2	----	----	----	----	----	----	----	----
1927	48,888	88.1	6,604	11.9	----	----	----	----	----	----	----	----
1928	33,116	43.2	43,542	56.8	----	----	----	----	----	----	----	----
1929	28,762	54.2	23,628	44.6	----	----	108	0.2	----	----	522	1.0

1930	54,266	69.8	23,479	30.2								
1931	39,733	30.7	23,235	17.9			7,712	6.0			58,833	45.4
1932	35,400	60.4	14,110	24.1							9,142	15.6
1933	40,553	46.9	19,084	22.1							26,824	31.0
1934	66,905	66.4	27,195	27.0							6,700	6.6
1935	76,672	71.8	20,628	19.3							9,500	8.9
1936	66,486	63.6	‡36,914	35.3							1,200	1.1
1937	73,593	45.1	‡88,507	54.2			1,200	0.7				
1938	49,931	23.4	‡153,869	72.2			5,100	2.4	3,100	1.5	1,100	0.5
1939	1,450	0.6	‡240,150	97.8			1,400	0.6	2,600	1.0		
1940			‡176,500	91.3			1,200	0.6	15,700	8.1		
1941			‡230,200	89.9					25,900	10.1		
1942			49,900	58.4			500	0.6	35,000	41.0		
1943			56,600	48.4					60,500	51.6		
1944			34,700	38.6					55,100	61.4		
1945			19,300	40.3					28,600	59.7		
1946			12,000	53.6					10,400	46.4		
1947			‡18,700	77.3					5,500	22.7		
1948			‡47,800	72.0					18,600	28.0		
1949			‡19,900	57.3					14,800	42.7		
1950			20,945	54.3	15,355	39.8			2,300	6.0		
1951			24,869	57.4	18,231	42.1			200	0.5		
1952			28,353	62.9	10,647	23.6			6,100	13.5		
1953			29,807	79.3	4,493	11.9			3,300	8.8		
1954			34,945	47.5	1,155	1.6			37,400	50.9		
1955			42,336	19.4	1,264	0.6			174,700	80.0		
1956			37,488	5.0	22,112	2.9	528,600	7.00	167,400	22.2		
1957			32,094	2.4	33,006	2.4	1,140,500	83.9	153,600	11.3		
1958			15,794	1.4	60,506	5.2	889,400	76.8	192,900	16.6		
1959			**9,958	0.6	**44,812	2.7	**1,438,959	86.7	**165,970	10.0		

* Probably includes Tomales Bay production.
† Probably includes San Francisco Bay Production.
‡ Probably includes Drakes Estero production.
** Converted from California Department of Fish and Game figures.

Water depth over most of the present beds at mean lower low tide is 1 to 2 feet, and at mean higher tide, $6\frac{1}{2}$ to $7\frac{1}{2}$ feet. Some of the higher ground is exposed during the lower low tides. The bed near the mouth of Walker Creek is exposed nearly every day at lower low tide (Figure 14), and is worked at such times. Areas under 1 to 2 feet of water at mean lower low tide may be exposed several times during a month depending on the height of the ground and the height of the tide. Most of the Millerton beds are exposed only occasionally, and they are worked on the high tides when there is enough water over them to float the scows and permit tonging.

The staked area south of Millerton Point (Figure 13), a bedding area of the Tomales Bay Oyster Company for many years, was abandoned in the 1940's because it was considered too shallow to work. Water over this area is now a foot or less deep at mean lower low tide, whereas soundings on the 1923 United Coast and Geodetic Survey chart show depths of 3 to 5 feet. State Public Health authorities say

FIGURE 14. Oyster bed at Hamlet, Tomales Bay.

an important factor in the accelerated silting at the lower end of the bay is the increase in number of homes along Lagunitas Creek that use the creek for their water supply. These so diminish the volume and velocity of flow that silt deposition from the creek tends to concentrate close to shore. Probably the company abandoned the area because it was unwilling to work the bed when the soft mud bottom was exposed. It is probably not impossible to grow Pacific oysters in the abandoned beds, because they can survive on soft mud bottoms and in somewhat

turbid waters. They are grown under such conditions in other California bays.

Tomales Bay is on the edge of the San Francisco Bay area, about 45 miles northwest of San Francisco. The bay is in an area that is very hilly, sparsely populated, and generally given over to dairying. Bay settlements consist of a few tiny hamlets along the east shore and the lower west shore, the only parts of the shoreline having a road. Communication with the more populous part of Marin County to the southeast and with San Francisco is by means of a winding road across the hilly Marin County peninsula.

Although the San Francisco Bay area has experienced large growth in some places, the population in the western part of Marin County has remained isolated and static. Recreational use of the bay is increasing (Tomales Bay State Park on the west side of the bay was created in 1950), and more attention will be drawn to the area when the Point Reyes peninsula is made a national park. However, the steep-sided shoreline, lacking accessible beaches, and ownership of much of the adjacent property by long-established ranches will probably prevent recreational development that would threaten the bay's small oyster operations. Commercial fishing and clamming have been carried on in the bay for a long time, but are very minor at present. Aside from a few small boat works at Marshall and Blakes Landing, a small herring fishery, and a few stores serving the local people and sportsmen, oystering is the bay's only commercial activity.

Pacific oyster planting in Tomales Bay began in the 1930's. The Tomales Bay Oyster Company at Millerton Point made an experimental planting in 1928 and subsequently made larger plantings, gathering their first significant harvest in 1935. This company is the largest of the two Tomales Bay oyster producers, and operates on privately owned tidelands.

In 1939 Henry Jensen made small plantings of Pacific seed oysters on his beds at Hamlet, which are supplemented by an allotment of 88 acres of State tidelands (Figure 13). In 1955 the business was taken over by Jensen's son who continues to maintain the small beds.

Another area in the vicinity of Tom Point, consisting of 150 acres has been held by a series of persons and companies. Pacific seed have been planted on it from time to time, but it has never accounted for much oyster production.

Pacific oysters have been the mainstay of the industry on Tomales Bay since their introduction. However, eastern oysters continue to be held by the Tomales Bay Oyster Company.

Drakes Estero

The history of oystering in Drakes Estero began in the early 1930's when Pacific oysters were introduced there. The estero is west of Tomales Bay on the Point Reyes peninsula (Figure 1).

The estero, an inlet of Drakes Bay, has the shape of a hand with the fingers representing five narrow inlets separated by low converging ridges, and the wrist representing the estero entrance from Drakes Bay (Figure 15). The thumb of the hand, Estero de Limantour, is separated from Drakes Bay by a low sand spit, and is not used for raising oysters. The entrance to Drakes Estero lies between cliffs about 100 feet

high, and the surrounding hills rise steeply from the water to heights of 200 or 300 feet. Small, rainy-season streams drain into the estero at the heads of the various inlets. The two most important streams flow into Schooner Bay inlet where silt deposition has made the upper part so shallow it is fast becoming marshland. The bottom mud is very soft, and this part is not used for bedding oysters.

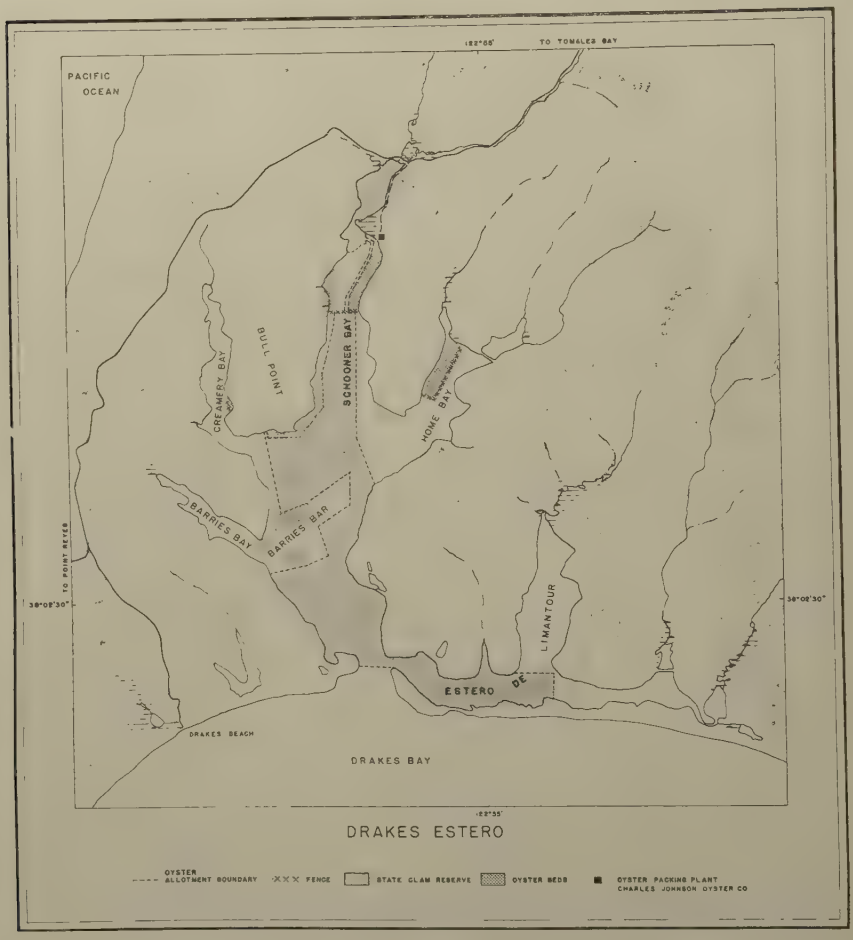

FIGURE 15. Drakes Estero, California.

Most of the oyster beds are in the estero inlets where they are fairly well protected from winter storm winds blowing from the southeast and southwest. The beds are on higher ground along the shore where they are exposed at most lower low tides (Figure 15). The bottoms of most of the beds consist of soft mud. Bulls Point has a firm sand and mud bottom and has been used for bedding small numbers of eastern oysters. At Barries Bar the bottom is sandy. Year-old Pacific oysters

are transplanted to this bed for fattening. The currents over the bed, which is in the middle of the estero near the mouth, are swift and only the larger oysters can maintain a hold on the bottom. The main seed bed is on soft mud on the west side of Home Bay inlet.

The area is very isolated, settlement consisting of a few ranches that use the surrounding land for grazing dairy cattle. The nearest village is 5 miles away on the west shore of Tomales Bay, and San Francisco is about 55 miles away. The only settlement on the estero is the house and packing plant of the oyster grower. A few sportsmen use the area for duck hunting by arrangement with the ranchers. The State Fish and Game Commission has reserved a large area in the central part of the estero for public clamming, but since access is difficult it is little used. The preserve also includes extensive eel grass beds, *Zostera marina,* which provide food for migratory black brant, *Branta nigricans,* making the estero attractive both for fowl and hunter. The eel grass grows mainly in the center of the estero, not along the sides where there are oyster beds.

The uniqueness and scenic attractiveness of the Point Reyes Peninsula have led the National Park Commission to survey its value as a national park. The recreational use of the area, including the estero, will undoubtedly increase and may have some effect on the oyster industry there; however, as long as the Fish and Game Commission has jurisdiction over the tidelands the oyster allotment can be held if Fish and Game requirements are met.

Bonnot (1938, pp. 194-195) sums up the early period of oystering on Drakes Estero with: "In 1932 and 1933 several test plants of Japanese seed were made in Drakes Estero. These were so successful that a corporation was formed and larger plantings have been made during the last several years. In common with most attempts to adapt exotic species to a strange environment, mistakes were made at first in the selection of suitable areas, but after several years of trial and error the merits and demerits of various parts of the bay have been determined. At present the beds are in a flourishing condition. Oysters have been marketed in increasing numbers from these beds for several years. The available growing area of the bay is extensive and there is still ample space for expansion."

After the successful test plantings, an allotment of 6,000 acres was granted in January 1934. The following year, the Drakes Bay Oyster Company was formed. It operated actively for a number of years, shipping oysters in the shell to San Francisco. In 1938 the company put up a small opening plant at the estero where they packed fresh shucked oysters to sell in San Francisco (Figure 16).

In 1955 the allotment was reduced to 1,165 acres, and the remainder of the estero was made a State clam and eel grass preserve (Figure 15). Of the 1,165 acres, about 200 are presently planted. Not all of the remainder is usable for oyster growing, but there is room for expansion within the allotted acreage.

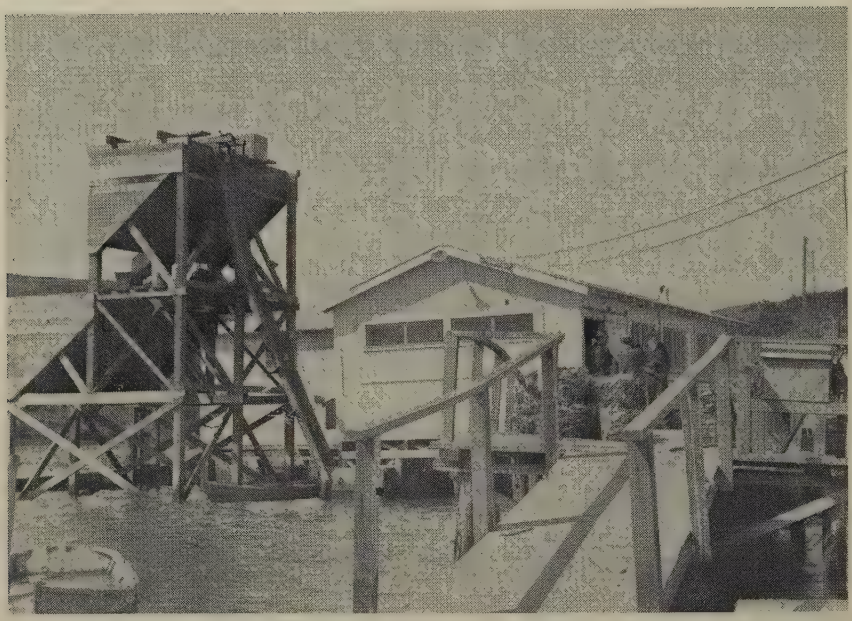

FIGURE 16. Drakes Estero oyster packing plant in the 1930's. *California Department of Fish and Game photograph.*

Bolinas Lagoon

Oysters were not raised in Bolinas Lagoon before 1955. An allotment of 240 acres covers the upper half of the lagoon, but the oyster bed is only a small part of it. Most of the lagoon is reserved by the State as a public clamming area (Figure 17).

The chief disadvantage of Bolinas Lagoon as an oyster growing area, besides its small size, is its polluted waters. For years the small town of Bolinas has dumped raw sewage into the lagoon and tidal currents carry it to the vicinity of the oyster bed. This situation has led the State Department of Public Health to require that oysters grown in the lagoon be cleansed in uncontaminated water, the oysters cleansing themselves by means of their water circulation mechanism in 3 or 4 days. U. S. Public Health regulations (1959, p. 21) state that oysters grown in polluted water must be kept in unpolluted water, the period of time depending on the temperature and salinity of the water and the initial bacterial quality of the oysters. The California Department of Public Health requires 30 days (Title 17, sec. 7732). The oyster company uses Bolinas Lagoon as a seed bed and transplants the oysters to its Drakes Bay beds for fattening, thus keeping them in unpolluted water for longer than 30 days.

Bolinas Lagoon lies on the San Andreas fault zone about 15 miles south of Tomales Bay and 17 miles north of the Golden Gate (Figure 1). Drakes Estero is about 25 miles away. The lagoon is triangular with hills rising steeply from the east and west shores. Although it is open to the south, separated from Bolinas Bay by a low, narrow sand spit, it

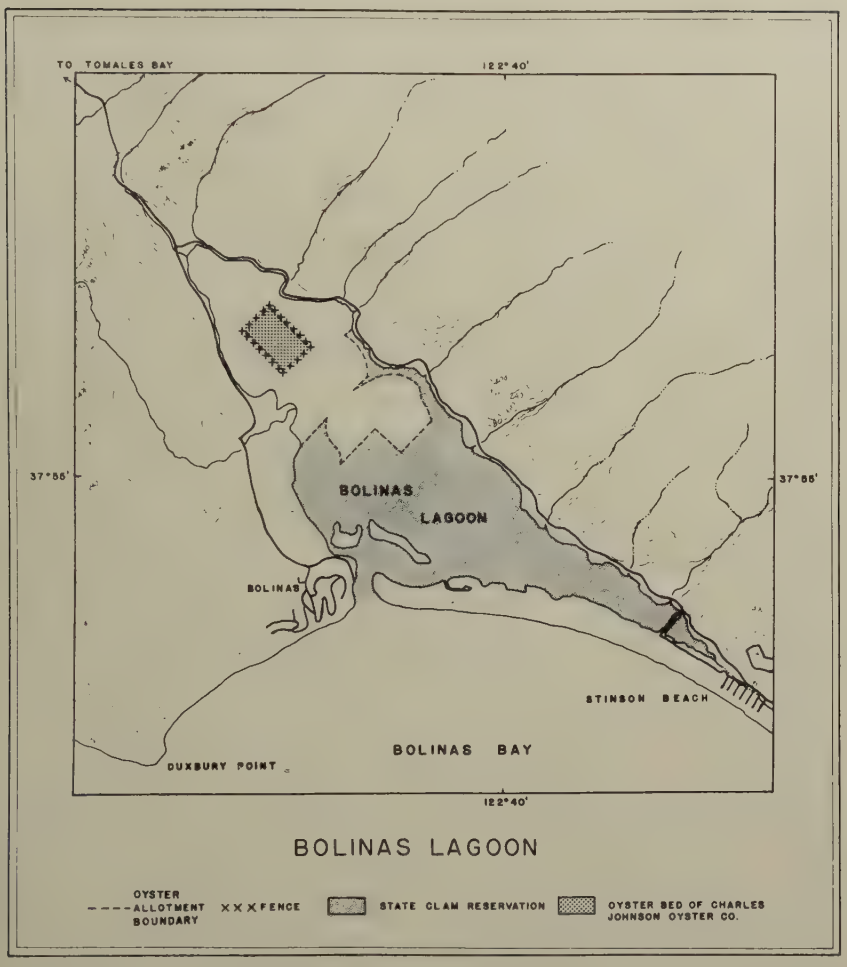

FIGURE 17. Bolinas Lagoon, California.

in generally protected. The surrounding hills are used for dairy herd grazing. There is no commercial activity on the lagoon except oystering. Little recreational use is made of it, although there is an active beach resort at Stinson, at the lower end of the spit.

Morro Bay

The history of oystering in Morro Bay is one of Pacific oyster culture. Native oysters do not grow in the bay, and only one attempt, in 1938, was made to raise eastern oysters there. The company decided the larger, faster growing Pacific oyster gave better returns.

Morro Bay is a very shallow lagoon, largely drained of water at lower low tide. It is separated from the Pacific Ocean on the west by a low sand spit which is sometimes overridden by waves during storms (Figure 18). Two streams draining into the bay, Chorro and Los Osos, enter on the east side where silt deposition has made a soft mud

bottom. This part of the bay is not used for bedding oysters. In the central bay, firm sand bottom is covered with a few inches of mud. Most of the 1,000 acres of allotments have similar bottoms.

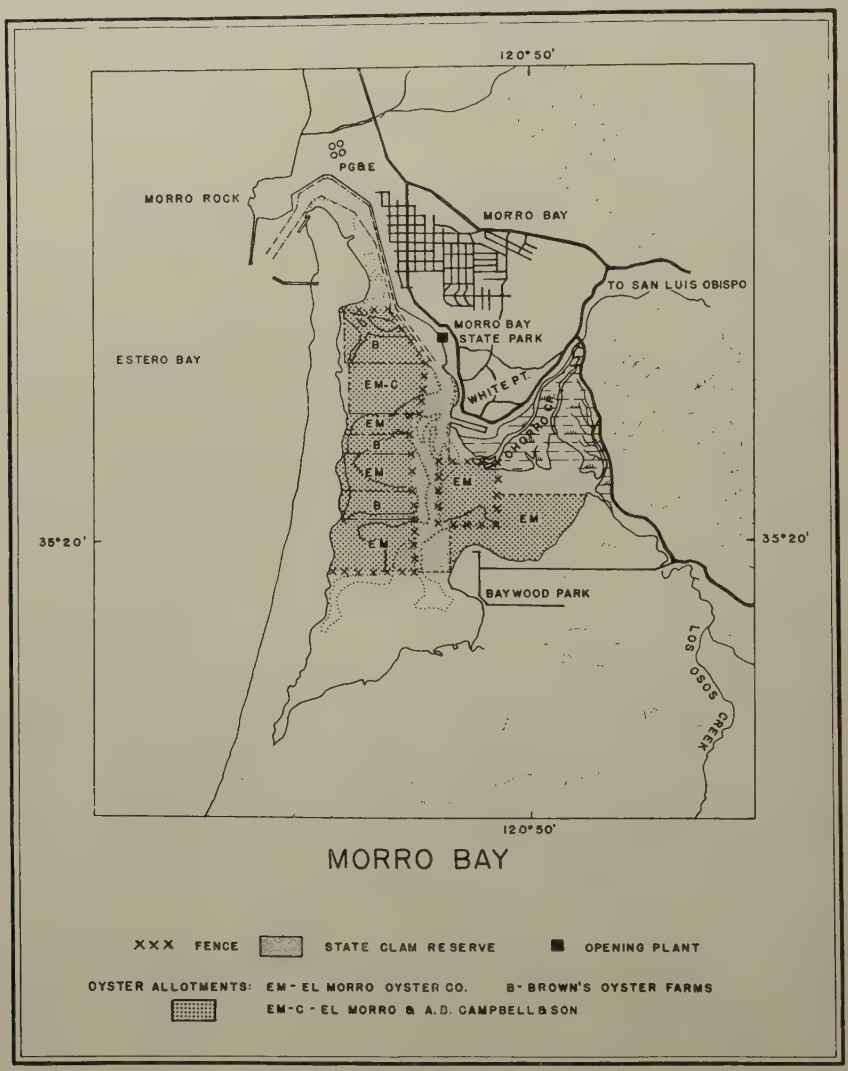

FIGURE 18. Morro Bay, California.

Pollution is not a problem in the bay. The town of Morro Bay, population about 4,000 in 1960, has a sewage disposal plant which discharges into the ocean, and the residential area at Baywood Park has septic tanks. The fishing fleet operating out of the bay is concentrated on the north end. A channel is kept open by dredging, but oyster growers say the dredging does not endanger the oyster beds. No other industries in the vicinity create conditions unfavorable to oyster culture.

Morro Bay is chiefly a resort area, particularly for people from the San Joaquin Valley who are attracted by its cool summer climate. The State in 1934 created a park just south of the town of Morro Bay and built a small boat harbor at White Point. The Fish and Game Commission has set aside clam reserves in the central bay along the tidal channels (Figure 18). Morro Bay is in a part of the State where the population is sparse and growing only slowly. San Luis Obispo, the closest town of any size, 20,000 in 1960, is 13 miles away. San Francisco is 230 miles north, Los Angeles is 220 miles south. Fresno and Bakersfield in the San Joaquin Valley are respectively 150 and 130 miles east.

The first planting of Pacific oyster seed in Morro Bay was made in 1932 by Bonnot and McMillin. Bonnot's report on the bay (1935, p. 73), made prior to the trial planting, was not very enthusiastic, but he later wrote (1938, p. 195) that the oysters from this planting did well despite lack of attention.

In April 1935, 1,677 acres of the bay were alloted. Oyster plantings were made in increasingly greater amounts each year after 1937. When shipments from Japan were cut off during World War II, the allottee obtained seed from the domestic set in Willapa Bay and thus continued in business. At that time Morro Bay became the leading oyster producing area in the State (Table 8).

Bonnot (unpub. report, January 1945) writes that for several years the Morro Bay Oyster Company had difficulty building up a market, but by 1941 had acquired stable outlets. During the war years, a nearby army camp took much of its production. However, the operations of the company, although successful, were restricted during the war by scarcity of help and limited seed supplies. The company discontinued plantings in 1948 and in 1950 gave up its allotments.

Beginning in 1950 a number of small producers acquired allotments and went into the oyster business in Morro Bay. Small commercial plantings of Pacific seed were made by these people in the early 1950's. Most of the oysters were marketed locally with the remainder finding outlets in the San Joaquin Valley *(Los Angeles Mirror,* January 8, 1953).

The El Morro Oyster Company and Browns Oyster Farms are now the principal producers in Morro Bay. In the fall of 1958 the El Morro Oyster Company opened a modern shucking and packing plant (Figure 19).

Humboldt Bay

Humboldt Bay consists of two shallow basins connected by a deep channel and separated from the ocean by sand spits (Figure 19). The bay's water surface at high water covers 24.5 square miles, and at low tide, 7.8 square miles (Washington State, 1955, p. 1), hence a large area is drained of water at lower low tide (Figure 20). Oystering is currently concentrated in the larger northern basin, Arcata Bay.

There is considerable settlement around Humboldt Bay, particularly Arcata Bay, where the towns of Eureka (population, 28,000 in 1960), Arcata (5,000), and Samoa (less than 1,000) are situated. In addition many industrial plants, principally saw mills and plywood plants, are active around the bay shore. Nevertheless, the only pollution has come

FIGURE 19. El Morro oyster packing plant, Morro Bay. *California Department of Fish and Game photograph.*

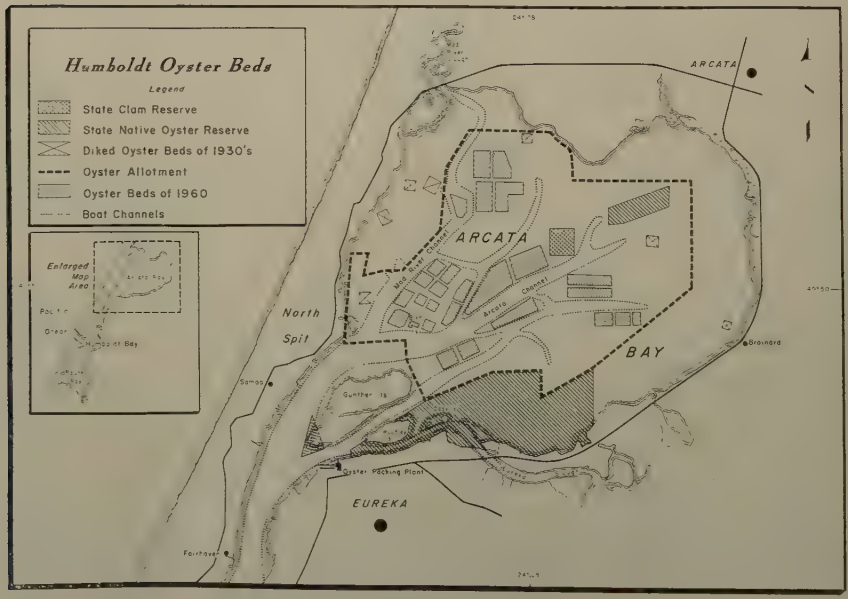

FIGURE 20. Northern Humboldt Bay oyster beds.

from Arcata's domestic sewage, a situation that has been largely corrected since 1958.

Two Kraft-type pulp mills are proposed for the north spit. The oyster industry in parts of Puget Sound was adversely affected by pulp mill liquor (Galtsoff, 1932). It is anticipated that wastes from Humboldt Bay mills will be emptied onto the ocean side of the spit. The Pacific Gas and Electric Company has a thermal power plant at Buhne Point opposite the entrance to the bay, but waste cooling water from it enters the channel 5 miles south of the oyster beds. This company is building an atomic power plant near its thermal plant, and the State Department of Public Health is testing the radioactive background of the bay and its aquatic life in order to be able to measure any increase that might result from operating the plant's nuclear reactor. Public Health officials and the management of the oyster company do not expect it will adversely affect the oysters.

Commercial navigation on the bay is confined to the main channel below Arcata Bay. The only commercial activity on the bay other than oystering consists of floating log-rafts down Mad River Slough to saw mills on the north spit, and this does not interfere with oyster operations.

Competition for recreational use of Humboldt Bay is of concern chiefly in South Bay where there is active hunting and clamming. Coast Oyster Company owns tidelands in South Bay, but has found the soft bottom and sluggish tidal currents limit its use to bedding seed, hence has not developed it. The Fish and Game Commission has set aside certain areas in Arcata Bay as clam reserves and native oyster reserves (Figure 20).

Efforts to raise Pacific oysters there began in 1953 when 20 cases of seed were planted on an allotment in northern Arcata Bay. This initial planting was successful, and a 100-case planting made in 1954 showed Pacific oysters could be grown in Humboldt Bay.

Commercial oystering was developed by the Coast Oyster Company, when large-scale plantings were initiated in Arcata Bay in 1955. The company has mechanized its operation to a large degree, principally by using a hydraulic dredge, and has achieved a scale of operations and level of production far greater than any other California producer (Table 8).

At the time Coast Oyster Company began operations in Humboldt Bay, a few individuals had recently begun working small allotments. Holdings there total nearly 5,000 acres, 3,460 of which are State allotments.

Elkhorn Slough

This long, narrow tidal inlet of Monterey Bay was the center of an oyster industry during the 1930's. The slough is thought to be an old channel of the Salinas River, the latter now emptying into Monterey Bay a few miles to the south (MacGinitie, 1935, p. 633). A sand spit at the mouth of the slough has formed a lagoon having a limited area of tidal flats. The main body of the slough is about 8 miles long and 100 to 300 yards wide, with a bottom of soft mud and lacking tidal flats (Figure 21).

Settlement on the shores of the slough is very sparse, the surrounding land being chiefly used for cattle grazing. The small village of Moss Landing is on the lower part of the spit. A salt works on the low land adjacent to the north side of the slough apparently did not affect the growth of oysters on nearby beds.

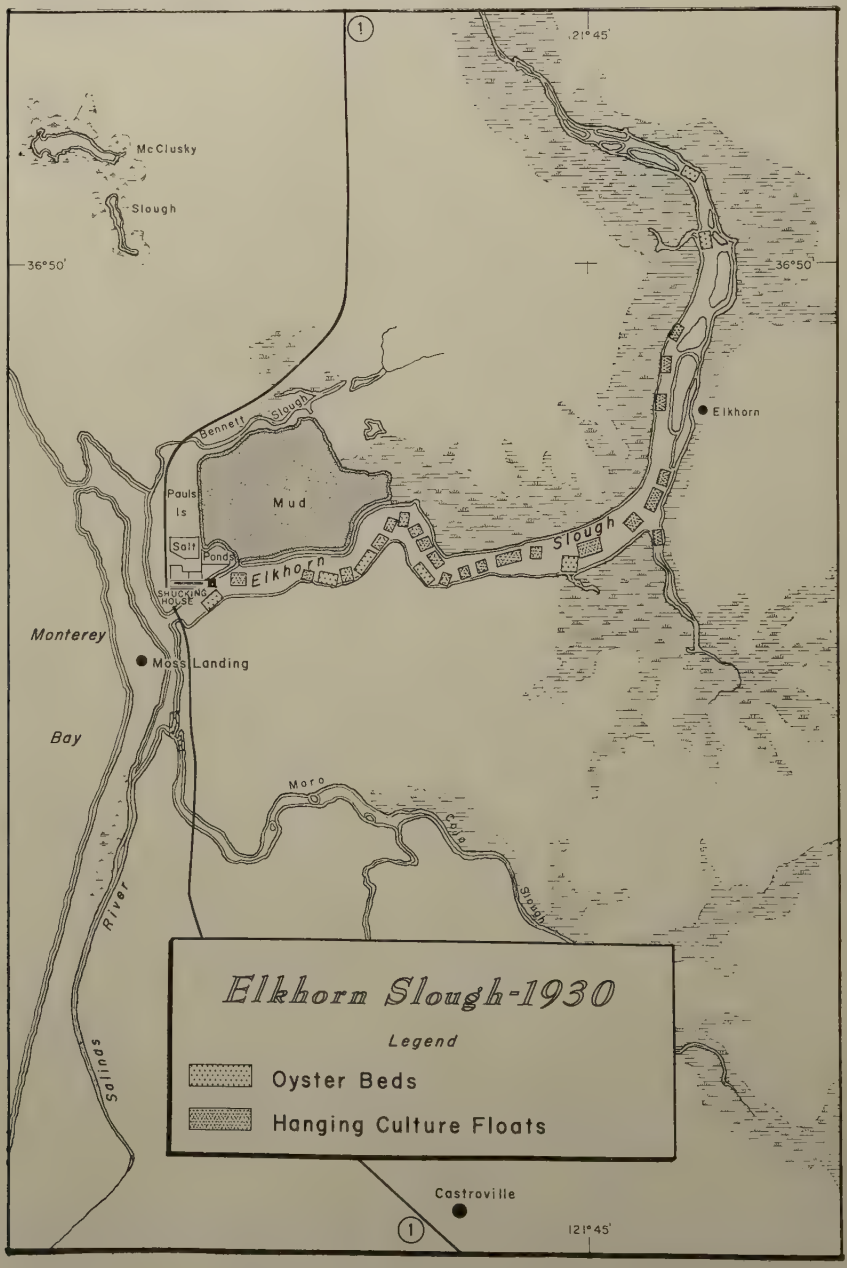

FIGURE 21. Elkhorn Slough in the 1930's.

Before the 1930's a few ill-fated attempts were made to raise oysters in Elkhorn Slough. In 1923 Consolidated Oyster Company of San Francisco made a trial planting, probably of easterns. A memorandum in the Department of Fish and Game files mentioning this planting states the company had difficulty finding suitable bedding ground and that the oysters were easily silted over. The company apparently never repeated the experiment. In 1926 several San Francisco oystermen worked the natural native oyster beds, greatly depleting them (Bonnot, unpub. report, 1933). An unsuccessful attempt to raise Mexican oysters in the slough was made in 1929 (Bonnot, 1935, p. 72).

The company that developed the Pacific oyster industry in Elkhorn Slough in the 1930's was West Coast Oyster Farms, Ltd. In the spring of 1930, they established several beds of Pacific oyster seed on the tidal flats in the lagoon and in the narrow part of the slough. Beginning in 1931, the narrow part of the slough was more fully utilized by adopting the Japanese method of hanging culture. The company imported seed set on tarred ropes which it hung from floats positioned over the deepest parts of the slough. A diked bed for growing native and eastern oysters was located on mud flats in Parsons Slough, a branch of Elkhorn Slough.

The hanging method appeared to be successful, and the company continued to import seed on rope until 1936. The first harvest of oysters grown by this method was made in the fall of 1932, the oysters having reached marketable size in only 1 year in Elkhorn Slough's warm waters (Table 3). The oysters were distributed to Monterey, Santa Cruz, Sacramento, San Francisco, and Los Angeles (*Pacific Fisherman,* October 1932, p. 70). The company had difficulty marketing its oysters in places where it was known that Japanese were involved in the enterprise. Furthermore, harvests were smaller than expected, and in 1936 West Coast Oyster Farms was taken over by the San Francisco International Fish Company (*Pacific Fisherman,* February 1936, p. 42). This company planted seed in the spring of 1936, but apparently this was the last planting in Elkhorn Slough until after World War II.

In September 1946, the long unused allotment at Elkhorn Slough was declared abandoned. An allotment covering the narrow part of the slough was granted, in October 1946. The allottee planted a small amount of Pacific seed, but did not attempt to establish a commercial enterprise. The oysters that grew to maturity were consumed, and when no further plantings were made, the allotment was declared abandoned. The next allottee for oyster culture in Elkhorn Slough made small plantings on the allotment, but did not pursue the venture, and the Fish and Game Commission declared the allotment abandoned in May 1960.

San Francisco Bay

The Consolidated Oyster Company began working with Pacific oysters in San Francisco Bay in 1933. Prior to bringing in the Pacific oyster, the company dealt exclusively in mature eastern oysters which it held in the bay for short periods before marketing. It continued to be principally interested in eastern oysters, even experimenting with raising 2-year-old seed (*Pacific Fisherman,* July 1933, p. 39).

FIGURE 22. Diked beds of Pacific oysters in south San Francisco Bay, 1933. *California Department of Fish and Game photograph.*

Bonnot, reporting on the California oyster industry for 1937 (1938, p. 195) wrote that the Consolidated Oyster Company had made several large-scale plantings of Pacific seed off South San Francisco (Figure 22), but the seed grew more slowly in San Francisco Bay than in some of the other localities where it had been planted. Since the company went out of business in 1939 no commercial plantings have been made in San Francisco Bay.

Bodega Lagoon

Several plantings made in the 1930's were described by Bonnot in his report of 1937 (1938, p. 194). He said: "In 1932 three small experimental plants of Japanese seed were made in Bodega Lagoon but the situations chosen were unfavorable and no returns were obtained. In 1936 a single test plant of 25 cases was laid out in what appeared to be a suitable location, and, as the results were encouraging, a much larger planting was made in the spring of 1937. The oysters from the 1936 planting are now of marketable size and the 1937 seed is showing a very good growth. . . . From present indications, the Bodega bed seems to possess the necesssary requirements for growing Japanese oysters successfully and in considerable quantity."

A note on the allotment record states the last planting was made in March 1938. The allotment was one of many declared abandoned in September 1946. There are no oyster beds in the lagoon at present.

Southern California

In 1932, Bonnot and McMillin planted Pacific seed oysters in experimental plots in a few southern California bays: Mugu Lagoon, Newport Bay, and Anaheim Slough. Mission Bay and San Diego Bay were considered too polluted for oyster culture. The oyster meat grew unsatisfactorily in the plantings made in Mugu Lagoon and Anaheim Slough and nothing further was done there. A small oyster enterprise, the Newport Oyster Company, was established in Newport Bay. *Pacific*

Fisherman (February 1933, p. 41) reported that the company, "operates beds and holding floats on Newport Bay for the production of domestic and imported cocktail oysters, and is now making deliveries." The nature of their operations is not clear, but the company may have been only concerned with native and eastern oysters, as the large Pacific oysters are not ordinarily used in cocktails.

Several allotments were made in Newport Bay in the 1930's, but production must have been quite small because none is reported in fishery statistics. The application for an allotment in 1939 brought a protest in the *Long Beach Press Telegram* (December 18, 1939) stating that the allotments interfered with extension of the yacht harbor and that the yacht club had been forced to buy up several oyster claims when the harbor was first developed. No oysters are grown in this area at present.

Recently allotments were acquired and plantings of Pacific and eastern oysters made near Point Loma, San Diego County, and in Catalina Harbor, Santa Catalina Island. This work was only experimental, and no commercial plantings were attempted. The 1960 planting of eastern oysters in Catalina Harbor was destroyed by stingrays.

OYSTER CULTURE IN CALIFORNIA

The fact that the oysters grown commercially in California do not reproduce in these waters has freed California oyster producers from the problems associated with obtaining a commercial set of oysters from natural beds. The industry's principal problem is selecting suitable bedding areas. The solution of this problem gave characteristics to California oyster culture that were different from those practiced in other United States oyster growing areas in the 19th century, and this led to its designation as the "California Method."

This method involves using upper tidal flats for bedding grounds, where the oysters are laid directly on the bottoms. The method grew from the experiences of San Francisco oystermen during the days of the Shoalwater Bay trade. These early oystermen learned bat stingrays would destroy the oysters unless the beds were fenced with closely set stakes. After oystermen began to raise eastern seed oysters, they established beds in other parts of San Francisco Bay, but they continued to place them on upper tidal flats where fencing was feasible. This practice was quite different from that on the Atlantic coast where plantings were in deep water and the oysters dredged or tonged.

Oyster Operations

By having beds on the upper tidal flats, oyster operations are tied to the tide cycle. In some areas the beds are exposed during the lowest of the low tides, and there the work of leveling and clearing the beds, breaking up clusters of oysters, and harvesting is often done when they are clear of water. The time of lowest tides is thus important; working the beds is made difficult if it occurs at night, as it frequently does in the principal harvest period, September through January. Harvesting must often be done during semi-darkness or when the beds are not entirely free of water. The work of breaking up oyster clusters can be more readily adjusted to daylight low tides. From March through

June, the lowest tide commonly occurs during daylight hours on the California coast.

In other areas the work is done when the beds are covered with enough water to float the boats and scows. As this happens during both of the daily high tides, the timing of tides is not so critical at these places.

The tideland oyster culture developed in San Francisco Bay spread to other areas in California (and the Pacific Northwest) where oystering was undertaken. Later oystermen have introduced variations to suit their locations and scale of operations, but planting on tidal flats and fencing to keep out bay stingrays has been continued.

San Francisco Bay, 1875 to 1910

The extensive marshlands along the west side of south San Francisco Bay forced the oystermen to locate their beds a considerable distance from the mainland (Figure 6). Because of this, the oyster companies built houses on the tidal flats near the beds (Figures 23, 24). These stations housed the men who worked on the beds, the crew shifting from one station to another as different beds required attention. They also provided protection from oyster thieves. Both the Morgan and Moraghan companies maintained houses at their Millbrae and San Mateo beds (Figure 6). None was at the Dumbarton and Belmont beds which were seed beds and required less attention. There were about six houses each near 50 to 100 acres of beds. They were supplied with fresh water from artesian wells which lifted the water a few feet above the high tide. Some stations added windmills to raise the water to tanks. One station piped some of its water to another station about a mile away (Townsend, 1893, p. 356).

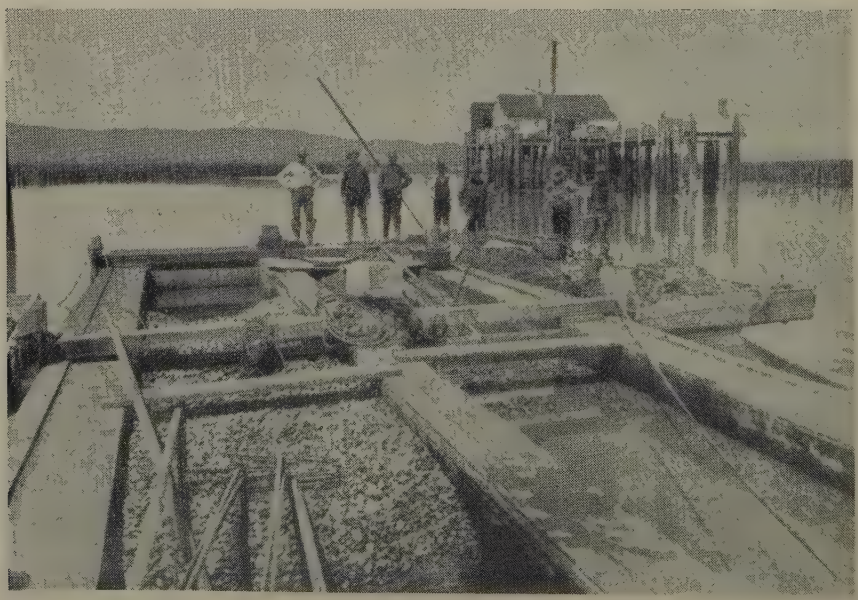

FIGURE 23. Oyster house and holding barges, south San Francisco Bay. *From Townsend, 1893.*

FIGURE 24. Eastern oysters on fenced beds, south San Francisco Bay. *From Townsend, 1893.*

Reports on the San Francisco Bay oyster industry state that about 100 men worked on the beds (Hittell, 1882, p. 364; Townsend, 1893, p. 358; Wilcox, 1895, p. 207). Townsend says that this number was increased considerably during peak activity, probably during harvesting for the winter holiday season and during seed planting in the early spring and fall. About 90 percent of the men were single, itinerant workers of Scandinavian origin, mainly recruited from the San Francisco waterfront.

The beds were on mud flats rather than on the extensive deposits of native oyster shell that occur along the San Mateo County shore. The latter were not good bedding grounds for eastern oysters because the small light native shells drifted easily, especially during winter storms, and formed an unstable bottom.

Different conditions prevailing in the several bedding areas accounted for some being used as seed beds and others as fattening beds. In the southern bay, storms are less severe and tidal currents are quite sluggish. As a result, the bottom is seldom disturbed, and small seed oysters are in little danger of being buried in the mud. For this reason, the Belmont and Dumbarton beds were used for raising seed oysters, which were later transplanted to the San Mateo and Millbrae beds.

At San Mateo and Millbrae, the tidal currents are swifter, bringing a greater inflow of ocean water. Experience showed that under these conditions oysters grew bigger and plumper, possibly because the greater amount of incoming water made more food available to the oysters. The position of the beds in relation to tidal currents was very important, and for this reason not all of the bottom land off Milbrae and San Mateo was equally good. A distance of 100 feet could mark the transition from a highly productive area to a poor one. In general the Millbrae beds were considered the best fattening grounds.

The beds required preparation before planting. When the tide was out, workmen cleared the area of vegetation growing on the mud flats and leveled the bottom. The cost of preparing the beds was great, sometimes as high as $100 per acre, according to the *San Francisco Chronicle* (February 6, 1898), but level bottoms made harvesting by tonging more efficient.

Old shell was commonly spread over the beds to form a firmer surface. Collins (1892, p. 156) reports that the leveled ground was spread first with a layer of eastern oyster shells and then with a layer of the smaller oyster shells.

Individual beds containing oysters of the same age were marked off by a few stakes which projected above high tide level. A much larger area of a hundred or more acres, containing many beds, was enclosed by a fence to keep out stingrays (Figure 24). The fence was made of 2- by 3-inch redwood scantling driven into the mud at 3-inch intervals. These fences also involved a considerable investment (Collins, 1892, p. 156, quotes a price of 12½ cents per piece of scantling) and required further expense for upkeep after winter storms. It was most important to keep the fences in good repair from March through September when stingrays are abundant in the bay.

When the seed arrived from the east coast, it was piled onto scows and taken to Dumbarton and Belmont to be spread by shovel as evenly as possible over the beds. After a year or two, the oysters were tonged up and transplanted to fattening beds. The *San Francisco Chronicle* (February 6, 1898) describes a double transplantation, but Townsend (1893, p. 357) mentions only one, saying that after several years on the seed bed the oysters were moved to a fattening bed for a year prior to marketing at an age of about 4 years.

By the time the eastern oysters at Dumbarton and Belmont were ready for transplanting, they were carrying a crop of native oysters which had set on their shells. The native oysters were not considered marketable and were knocked off with an adze-shaped instrument adapted to the purpose. Although small, the native oysters were considered undesirable in that they used food that otherwise would have been available to the eastern oysters. Barnacles also attached to the shells of eastern oysters and had to be removed.

When ready for harvesting, the oysters were tonged up onto scows while the beds were under water (Figure 25). The scows were of different sizes, but an average one was 8 by 24 feet. When the amount of oysters needed had been taken up, the scows were poled back to the station where they were tied to floats. There the oysters were sorted, cleaned, and put into the floats to keep fresh while waiting shipment to market (Figure 26). The floats were large barges with their bottoms slatted to allow water circulation. They were kept afloat by air-tight compartments fixed along the sides and ends, and extra large floats, lengthwise through the middle. The double floats were 40 by 20 feet (Townsend, 1893, p. 358).

Small sailing boats called "plungers" and rowboats provided general transportation among the beds.

Oyster shipments were carried to the San Francisco market in small sloops. Oysters were packed in boxes containing about 150 large or 250 standard-sized ones and loaded onto a sloop which could carry about

FIGURE 25. Tonging eastern oysters, south San Francisco Bay, 1890's.
From Townsend, 1893.

FIGURE 26. Workers on oyster floats, Millbrae beds, south San Francisco Bay, 1890's.
From Townsend, 1893.

150 boxes (Collins, 1892, p. 157). Native oysters from Washington and Oregon were packed in sacks containing about 1½ bushels. About 300 boxes and 60 sacks were taken daily to the San Francisco market.

Tomales Bay

Early oyster cultivation in Tomales Bay probably was similar to that in San Francisco Bay, but on a much smaller scale. Up to the present, the practices of tonging and holding harvested oysters in floats have been carried on by the Tomales Bay Oyster Company whose long-time manager was an employee of the Morgan Oyster Company on San Francisco Bay. The Tomales Bay Oyster Company harvests Pacific oysters from its 28 acres of beds when they are 3 years old, 1 year to 6 months older than oysters harvested in other areas. By harvesting larger oysters the company reports it obtains a greater gallonage per acre.

Morro Bay

A large part of Morro Bay is drained at the daily lower low tide, and much of this exposed area has a firm bottom. Oystermen have found that under these conditions it is convenient to carry on some of their operations when the bottom is exposed.

FIGURE 27. Wire collecting-baskets and steel-mesh drum used in harvesting Pacific oysters at Morro Bay. *California Department of Fish and Game photograph.*

Planting, however, is done when the beds are under water, the seed oysters being shoveled from scows over the 300 acres of beds. Only firm bottoms are used as bedding grounds, so no distinction is made between seed beds and harvest beds, and there is, therefore, no transplanting operation. Clusters are broken up by hand when the beds are exposed, workers use a hand-pick for this task. When strong winds cause the oysters to pile up, they are rescattered by hand.

Oysters are harvested after they are about 2 years old. Nearly every day of the week oysters are brought in from the beds to fill orders. Men go out at low tide taking wire baskets which they fill with oysters picked up by hand. When full, the wire baskets are emptied into larger steel mesh containers which have been deposited here and there in the harvesting area (Figure 27). When the tide comes in, the mesh containers are lifted onto scows by the hoisting gear of the company's power boat and taken to the packing plant. The use of the mesh containers and mechanized handling of them began in 1958 when the El Morro Oyster Company opened its new plant.

Drakes Estero

Planting operations in Drakes Estero are much the same as in Morro Bay. However, the varied qualities of the 200 acres of beds make it necessary to transplant from some of them. The transplanting operation involves picking up young oysters from the seed beds at low tide, and then, when the tide comes in, taking them to fattening grounds and scattering them over beds there. Pacific oysters are harvested by hand, and at times a few eastern oysters, bedded in a deeper part of the estero, have been tonged (Figure 28). The oysters are collected in wire bushel baskets and carried to nearby scows. When the incoming tide floats the scows, they are towed to the packing plant on the shore of

FIGURE 28. Harvesting Pacific oysters at low tide at Drakes Estero.
California Department of Fish and Game photograph.

Schooner Bay inlet. The oysters are dumped onto a conveyor belt which carries them into a bin over the opening table inside the plant. The company has used a unique airboat which travels over very wet, soft mud and makes it possible to reach the beds during low tide (Figure 29).

FIGURE 29. Airboat used for traveling over soft mud flats, Drakes Estero. *California Department of Fish and Game photograph.*

Humboldt Bay

The effort to raise native oysters in Humboldt Bay in the 1930's involved using diked beds built on the tidal flats. This method was borrowed from native oyster growers in Puget Sound, Washington, where it is employed to keep a foot or so of water over the oysters during ebb tide to mitigate the effects of extreme summer and winter air temperatures. Although freezing temperatures do not occur in Humboldt Bay, diked beds were adopted to keep the oysters from being exposed and to permit continuous feeding. Most of the diked beds were on the upper reaches of Arcata Bay where they were exposed during most low tides and where the tidal currents were weak. Later experience showed these were the poorest feeding grounds. The dikes further obstructed mixing of the water over the beds. These factors probably accounted for the slow growth and poor quality of oysters on diked beds.

The low walls of the dikes were made of redwood siding held up by stakes driven into the mud. The leveled bottom was spread with shell and gravel to keep small oysters from sinking into soft mud. Similar diked beds were used in south San Francisco Bay for a short time to

grow Pacific oysters (Figures 30, 31). Eastern as well as native oysters were raised on the Arcata Bay diked beds.

FIGURE 30. Diked, gravelled bed under construction, south San Francisco Bay, 1933.
California Department of Fish and Game photograph.

FIGURE 31. Series of diked beds, south San Francisco Bay, 1933.
California Department of Fish and Game photograph.

Since 1955 a large-scale, mechanized oyster-growing enterprise has been operating in northern Humboldt Bay (Arcata Bay) where Coast Oyster Company has developed several hundred acres of beds. To operate such a large area, power equipment is both feasible and necessary. The hydraulic dredge, which picks up oysters in transplanting and harvesting operations, was introduced in 1956. It saves considerable labor costs as the two men who operate it can do as much work as a dozen or more men working without it. The dredge is also a great boon to oystering on Arcata Bay because most of the bay has a soft,

sticky mud bottom (Figure 32) making working the beds at low tide difficult.

About one-third of the developed acreage is seed beds or marginal beds which the company intends to bring into use as seed beds by applying layers of crushed oyster shell. Most of the seed is planted in seed beds and after about a year is transplanted to fattening beds, but the fact that two-thirds of the acreage is harvest beds means that some seed is planted directly on the harvest beds.

FIGURE 32. Hand harvesting Pacific oysters from a soft-mud bed, Arcata Bay. *California Department of Fish and Game photograph.*

The company has now used all of the tidelands it considers suitable for harvesting, and when it has developed an equal acreage of seed beds, it will no longer be able to increase production by planting more tidelands. Then attempts to increase production will center around reducing handling losses, raising larger oysters, and perhaps improving the feeding conditions in certain areas by artificial means. In recent years experiments have been made in various oyster growing regions, particularly Australia and Japan, to artificially feed oysters by putting nitrogen or phosphate solutions into the water. If artificial feeding ever becomes feasible on a commercial scale, it would be of great value in Humboldt Bay, permitting production in areas that at present are of limited or no value as oyster land because they lack sufficient nutrients.

Harvest or fattening beds are located on the mud flats just off the main tidal channels where strong currents bring a plentiful supply of water and food. The Bird Island beds at the mouth of Arcata Bay between the Mad River and Arcata Channels are in the best position, and oysters grow faster and fatter there. Upstream from Bird Island, however, the current diminishes and the beds are marginal. The beds in the lee of currents passing Gunther Island are marginal for the

same reason, as are those immediately to the south of the main branch of Arcata Channel. The currents diminish toward the upper parts of the bay and along its margins, making these areas less valuable.

The tidal flats at the head of Arcata Channel have not yet been utilized because of their marginal value as feeding grounds, the very soft mud bottom, and water pollution. When the present oystering operation began in 1955, approximately the eastern third of the bay was declared polluted, but the level of pollution did not make the water so turbid that the oysters could not feed. Seed oysters grown in polluted water were transplanted to clean water for fattening, thus meeting Federal and State public health requirements. In 1958 the town of Arcata put into operation a sewage disposal plant. This resulted in less pollution of the areas below the channel where beds are located.

Bottom conditions vary over the Bay. The firmest ground is where strong currents prevent thick silt deposits from accumulating and the bottom is composed of mud and sand. The beds in the vicinity of Bird Island and one farther up the Mad River Channel have the firmest bottoms. These areas combine the best conditions for feeding: strong currents which bring fresh food supplies and firm bottoms which allow free water circulation around the oysters. Oysters grown in soft mud tend to sink into it, often leaving only a small part of the valves free. This inhibits feeding activity and results in reduced growth of oyster meats. During storms oysters in soft mud are easily buried and lost.

Oysters grown on firm bottoms are, however, not always well anchored and are subject to shifting during storms. Oysters on the harvest bed in the "island" in Mad River Channel are blown into windrows when northwesterly winds are strong, and are re-scattered by dragging a harrow over the bed with a diesel launch.

When the seed oysters arrive, usually in March, they are promptly unloaded from the ship and transferred to planting barges. The arrival of a shipment involves handling a very large amount of seed within a short period of time, but the company has developed methods of facilitating this work. The single annual shipment is almost mandatory as it is difficult to find ships on the trans-Pacific route that will go out of their way to call at Humboldt Bay.

Until the 1958 planting season, the seed oysters were shovelled over the Humboldt beds, the same planting method used in other areas. The length of time and labor costs involved, as well as the difficulty of properly scattering the seed, led the Coast Oyster Company to devise a mechanical means of spreading the seed. Planting by hand requires that the seed be thrown off the shovel with a twisting motion to scatter it. As the men tired they spread the seed less evenly and the resulting heaps had to be scattered by hand when the beds were exposed, a difficult job because of the large area involved and the soft bottom.

The two mechanical spreaders devised by the company are steel scows, 18 by 50 feet, fitted with conveyor belts; one scow has one conveyor belt running down the middle, while the second has two. At the end of the scow, below the end of the conveyor belt, is a rotating blade run by a separate motor. The seed is caught by the blade as it falls off the conveyor belt and is thrown into the water. At the beginning of planting, the scow is entirely filled with seed which is kept off the conveyor belts by steel plates placed over them. As the seed at the

front of the scow falls onto the belt and the pile diminishes, the plates are removed to regulate the flow of seed onto them. The spreading scow is towed back and forth over the bed until all seed is planted.

The number of cases of seed put on the scow for planting depends on the size and quality of the bed. Many of the beds are squares of 18 acres or multiples thereof as this is a convenient size for the hydraulic dredge. To plant about 9,000 cases takes 4 or 5 days. The necessity of getting the seed into the water quickly means that planting is done under all but the most severe weather conditions.

Transplanting from the seed beds to the harvest beds begins after the oysters are 12 to 18 months old, when the oysters are picked off the bottom by the hydraulic dredge.

The dredge is a steel barge-like structure 24 feet by 70 feet, equipped with a 100-horsepower diesel motor which provides power to operate the dredge's machinery. On one side of the barge is a well 8 feet wide and 35 feet long containing a conveyor belt 3 feet wide and 48 feet long. During operation the belt is lowered into the water on a pulley to a position a few inches above the bay bottom. A hood 7 feet wide fitted with pumps and water jets is attached to the forward end of the belt, and the force of the water jets, thrown parallel to the bottom and several inches above it, causes a vacuum which pulls the oysters onto the conveyor belt, whence they move by a series of three other conveyor belts to a loading scow moored on the other side of the dredge.

When operating, the dredge is towed in a spiral path, working a 7-foot strip. If necessary the dredge is operated at night and in the frequent heavy fogs, with the aid of a floodlight.

During transplanting operations, the dredge separates the oysters in the larger clusters. The company plants mixed broken and unbroken shell, so the amount of separation is lessened because clusters growing on the broken shell usually contain only three or four oysters and it is not necessary to separate these. Replanting is done by hand because the action of the revolving blades on the planting machine tends to chip the shells, often causing oyster mortality. Transplanting is done from about January through August. Each year's crop is planted and transplanted separately so the company can harvest oysters of the same age and about the same size. The oysters are about $2\frac{1}{2}$ years old when harvested.

In addition to the hydraulic dredge, the company operates a drag dredge, the harvesting equipment most widely used on the Atlantic coast. It was used in Arcata Bay before the hydraulic dredge was brought into operation and is still used to pick up oysters left in the corners of the beds by the hydraulic dredge. This dredge is equipped with two booms which raise and lower the dredges. The latter are chain-mesh bags which operate like a snap-purse. They are dragged along the bottom in an open position, and are raised over the deck of the dredge where the bag is emptied. A disadvantage of this method is the large number of oysters injured. This kind of dredge operated on soft, mud bottoms also has the disadvantage of causing oysters to become muddy.

Harvesting usually begins in September and continues into June, depending on the condition of the oysters. If water temperatures are high enough during the summer to induce considerable spawning and continue high in the fall, harvesting is delayed. This may push the

beginning of the harvest up to late September or sometime in October. Depending on conditions prevailing in a particular year, harvesting may close down completely during all or part of the summer, or continue at a reduced level. Harvesting reaches peaks in the winter holiday season and in the spring Lenten season.

The hydraulic dredge harvests oysters 3 or 4 days each week, depending on demand. For the remainder of the work week it is used in transplanting work. The marketable oysters picked up by the dredge are loaded onto self-unloading steel scows, also used for planting, and towed to the packing plant on the Eureka waterfront. There the conveyor belt on the scow is lined up with the elevator belt which raises the oysters to the upper story of the packing plant. Jets of water at the lower and upper ends of the elevator belt clean mud and debris from the shells.

Coast Oyster Company employs the following equipment to carry out the operations described above: hydraulic dredge, self-powered drag dredge, self-unloading steel scows with devices for planting seed oysters, wooden scows, 30-foot power tow boats, outboard motor boats, and a 55-foot diesel launch. To operate this equipment requires very little crew. Under the direction of the company's general manager, a man in charge of operations on the bay, his assistant and one or two other men carry out the work except during the planting season when about a dozen extra men are employed to unload the cases of seed and tend the planting scows.

OYSTER PROCESSING

All but a very few of the oysters produced in California are sold fresh, and nearly all of these fresh oysters are shucked and packed by the producers. One company now produces frozen oysters in bulk containers and is experimenting with packaging frozen oysters for the retail trade, the first time oysters have been processed by this method in California. The same company experimented with canning oysters and oyster soup but has discontinued these operations. No smoked oysters are produced in California.

Present methods of processing fresh oysters have not changed much from those employed in the 19th century, the most significant innovation being refrigeration, introduced in the 1920's. Tin containers used in the early days have been largely replaced by glass.

California Public Health regulations cover all aspects of oyster packing: plant layout, screening, lighting, ventilation, water supply, sewers and drains, facilities for employees, equipment and plant cleaning, conditions under which oysters must be packed, and general type of containers to be used. These regulations, setting forth the minimum requirements for sanitary shellfish processing, are aimed at preventing contamination, particularly by pathogenic organisms of fecal origin such as typhoid and paratyphoid. Only those processing plants which meet Public Health standards are allowed to operate, and they are given a certificate requiring annual renewal. California Public Health regulations (*Administrative Code*, Title 17) include the provisions of the United States Public Health regulations (U.S. Public Health Service, 1959).

The Plant

The shucking plants in use today have basically similar designs. They contain an opening room, a packing room, and a refrigerator room. The similarity is due to the practicality of the plan and the Public Health requirement that the opening and packing operations be separate. Refrigeration facilities to keep the oysters at 50°F. or below are required except where the shucked oysters are sold immediately to the customer.

The opening room is usually long and narrow, largely filled with a metal-top table over which has been built a bin reaching from the ceiling to within 12 or 15 inches of the table top. The bin is filled with oysters from overhead facilities. Coast Oyster Company's bin at Eureka is 90 feet long and 6 feet wide, with a maximum capacity of 2,600 bushels. It is filled from a conveyor belt about 40 feet long which runs on tracks built over the bin's top. As oysters enter the plant at the second story via an elevator belt they drop onto the movable conveyor belt, and fall from the end of this belt into the bin. After part of the bin is filled, the belt is pushed forward on its tracks to fill the next part. This permits filling a part of the bin when there are not many oysters and only a small opening crew is working, or filling the whole bin to any desired level. The bin is usually filled in the late afternoon after the openers have finished for the day. The table is washed down and a layer of flaked ice is laid over it. Then oysters harvested earlier in the day are piled into the bin from above and ice is spread over the oysters in the bin. The ice is carried from the ice machine to the upper story on a conveyor belt. The oysters are thus kept cool overnight and ready for the openers the following morning.

At Morro Bay the opening room arrangement of long table and overhead bin is similar to that at the Eureka plant, but the arrangement for bringing in the oysters is different. The mesh drums into which the oysters are collected on the harvesting ground are brought directly into the plant on a moving cable which runs over the bin. When the drums are in position over the bin, they are tipped and the oysters emptied out. The cable carries the empty drums out the other end of the building where they are stacked.

At Drakes Estero the small size of the bin, about 6 by 3 feet, requires no arrangement for spreading the oysters over its length. They are dropped directly into it from the conveyor belt bringing them up from the scow.

Opening

The opening table at the Eureka plant will accommodate about 60 openers working on both sides of it. Women are employed for this work. At Morro Bay 20 is the maximum number of shuckers able to work at the opening table. At the Drakes Estero plant there is room for six to eight openers around the table. At the small Tomales Bay oyster establishments the oysters are opened at a small table. Openers are paid by the quantity of oyster meat shucked.

Openers use a knife shaped like an ice-pick except that a blade replaces the pick. The blade is about one-fourth inch wide with a blunt end. The oyster is opened by prying the knife between the valves and severing the adductor muscle, which holds them shut. The valves are

then pulled apart, and the oyster is freed from the left valve by cutting the muscle from that side.

Other methods of opening oysters have been tried. Some of the oyster companies in Louisiana employ opening machines, but they have not been found adaptable to Pacific oysters. Experiments with chemical baths which anaesthetize the oyster and relax the adductor muscle, causing the oyster to open, also have not been successful.

When the oyster is open, the opener lets the meat fall into a stainless steel container and drops the shells into a chute attached to the table at her side. The shells slide down the chute to a conveyor belt which runs in a slight depression in the floor under the table.

The shells are thus carried out of the plant to a shell crushing machine on the waterfront just below the equipment docking area. As the crushed shells leave the machine, they pass onto another conveyor belt that runs across a short wharf and dumps the shell onto a scow. About once a week the scows, fitted with a suction pump and fire hose, are towed out to beds which the company is improving by hardening the bottom. Crushed shell is used because it will pack down and form a firmer bottom than whole shell. The shell is spread over the bed by washing it off the scow with a jet of water from the fire hose. This results in somewhat uneven spreading, but it is a convenient way of getting large quantities of shell on the beds. Many applications of shell are needed to make the bottom firm and continuing applications are needed to maintain this firmness.

Shell disposal differs at the other plants. At Morro Bay it is taken out of the plant on a conveyor belt, deposited onto an elevator belt and raised up to a storage bin. When the bin is full, its contents are let out the bottom into a truck and hauled to a dump. The company has no use for the shell as the beds it maintains are on firm substrate, and there is no commercial demand for the shell. At Drakes Estero the openers drop the shell into large galvanized garbage cans so they eventually can be taken out and spread on the softest beds.

Washing

A worker collects the oyster meats from the openers in 2-gallon stainless steel containers which are passed into the packing room through a window separating the two rooms. California Public Health regulations state that shucked shellfish cannot remain on the shucking tables for more than 1 hour unless they are cooled to 50°F. or below. At these temperatures pathogenic or toxin producing bacteria growth is ordinarily inhibited. The oyster meats are cooled by removing them to washing machines where cold water both cools and washes them.

At the Eureka plant, the oyster meats are emptied into two 40-gallon washing machines filled with a constant flow of cold (34° to 36°F.) water supplied from a 1,000-gallon self-refrigerating tank. Air, blown through the water from below, creates an agitating motion which frees the oyster meats of mud, grit, or shell fragments. A perforated plate set a few inches above the bottom of the washing machine keeps the oyster meats from settling on the bottom.

While washing is necessary and required by the Department of Public Health, it does have some adverse effects on the oyster meats. According to experimental work done by Pottinger *et al.* (1941, pp. 3-6),

washing in fresh water for 3 minutes will cause oyster meats (in this case eastern) to increase their weight by 1 to 12 percent. Knowledge that oysters absorb fresh water is as old as the oyster business. Floating oysters in fresh water and allowing them to swell up and look plump, is an old trick of unscrupulous oyster dealers. The oysters gradually lose this water and the consumer finds he has smaller oysters than he bought.

Absorbed fresh water not only gives oyster meat a false plumpness, but lessens its nutritional value by leaching out soluble minerals, according to Pottinger *et al.* (1941, pp. 3-6). However, the authors point out some fresh water must be absorbed because washing is necessary to clean the meats of mud, shell, and bacteria, but prolonged soaking in fresh water should be avoided. The normal washing time in California packing plants is therefore kept down to 3 to 5 minutes.

Packing

Oysters, once washed, are emptied onto the grading table for packing. The table is made of stainless steel and perforated for drainage. The oysters are sorted by size and immediately put into containers. Any mud or shell still clinging to the meats is washed off with spray hoses hanging over the table.

The stainless steel equipment and utensils in the opening and packing rooms meet Public Health regulations requiring that all surfaces, utensils, and equipment be made of impermeable material that can be thoroughly cleaned and not provide places where bacteria might grow.

Six or eight women usually work at the packing table in the Eureka plant. Odd-sized oysters are sorted out and packed separately. Oyster meats that have been cut by the openers are removed as they are not marketable. The cut oysters are collected in a large container kept in the refrigerator room and picked up from time to time by the manager of a local mink farm who buys them for 10 cents per gallon.

The oysters are packed in whatever containers the orders for the day specify. These are stacked on a portable table, covered with lids, and taken to the nearby sealing machine which clamps on the lids. There is another machine in the Eureka plant that seals gallon cans. The individual containers are packed in shipping boxes when they come off the sealing machine and are then put in the refrigerator room where the temperature is 32° to 34°F. When the oysters leave the plant, ice from the company's flake-ice machine is packed around the jars or cans in the shipping boxes.

Packing operations at Morro Bay are very similar, although the company does not have its own ice machine and fewer packers are used. This is also the case at the small Drakes Estero plant. There, two women do all of the packing. The jars are sealed by a manual device.

The fresh eastern oysters produced in San Francisco Bay during the 1870-1910 period were packed in square tins and hermetically sealed. Paper cartons were popular fresh-oyster containers during the 1930's. Such containers would not be permissible today as Public Health regulations require containers made of impermeable materials which can be sealed in such a way that tampering may be detected. Glass jars came into use in World War II and today they are the most common container for fresh packed oysters, the standard size containing 12 ounces.

The entire pack at Morro Bay and Drakes Estero is put up in jars. Coast Oyster Company commonly uses jars too, but also packs fresh oysters in cans. These cans have a plastic window at one end to permit customers to see the oysters. The old practice of supplying fresh oysters to retailers in bulk containers from which they sold small quantities to their customers has been done away with by Public Health regulations governing repacking.

Labeling

Labeling information is printed on the lid of the jar, making labeling equipment unnecessary. The lids are ordered from a manufacturer with the information printed on them. They are metal faced with cardboard, and have crimped edges which clamp over the jar tops providing an airtight seal. The tin cans used by Coast Oyster Company are provided by the customer with a label.

Public Health regulations require that the name of the shipper, Public Health certificate number, and date of packing appear on each container. The date may appear in code if it is registered with the State Department of Public Health. The shipper listed on the label is not the producer, as the latter ordinarily does not distribute the processed oysters. Shippers or distributors are wholesale fish dealers or brokers who have their oysters packed under company or brand names. One producing company has its own brand name which is distributed through a brokerage firm; however, it is the broker's name that appears on the label. The consumer who knows nothing about the oyster business has no way of telling where the oysters he buys were produced. The practice of coding the packing date is followed in order to avoid marketing difficulties which would arise from consumer ignorance of the keeping qualities of fresh-shucked oysters.

Storage

The keeping qualities of oysters after they have been taken from the beds is a matter of concern to producers, Public Health authorities, and consumers. Oysters in the shell are able to survive out of water for considerable lengths of time if water is trapped within their valves, but after oysters have been killed by shucking, the meat deteriorates more rapidly.

Various studies have been made to determine how long fresh packed oysters will remain fresh. Work done by Stern *et al.* (1957, pp. 7-13) revealed a test group of Pacific oysters held at 53°F. spoiled after 7 days, and groups held at 36°F. and on ice were still acceptable after 16 days. Earlier experiments (Francis P. Griffiths, *Pacific Fisherman,* September 1937, p. 49; and Piskur, 1947, p. 23) showed that good quality oysters in airtight containers packed in ice or under refrigeration at 32°F. to 34°F. will remain in good condition for 10 to 13 days.

Frozen Oysters

At present the only frozen oysters produced in California come from Humboldt Bay, where about 10 to 15 percent are frozen. This operation began in the fall of 1958. The oysters are packed in gallon cans and frozen at a neighboring ice plant. They are stored in the company's refrigerator room until picked up by the buyer.

Canned Oysters

There are no oyster canning operations in California at present. Coast Oyster Company experimented with oyster canning and oyster soup for a short time in 1956, 1957, and 1958. However, they found the fresh market would take all of the oysters they produced, so they closed their Eureka cannery.

THE OYSTER MARKET

California oysters have always been largely marketed within the State, particularly in the larger towns and cities. San Francisco has traditionally been the chief market. However, when oyster production has been most active, shipments to other western states have been made. The limited room for expansion of production in California and the fast growing population of the State are factors that indicate the supply of oysters locally grown will not become excessive compared with the demand for them.

The present fresh oyster market in California is dominated by Pacific oysters, most of which are supplied by California growers. Substantial amounts are also imported from Washington. Fresh eastern and Olympia oysters are available in limited quantities in some areas.

A factor still influencing oyster marketing is the "R" month myth, which states that oysters should not be eaten during months whose names do not contain the letter "r." This old idea is based on the fact that the months lacking the letter "r," May through August, coincide with the oyster spawning season. During this time, oysters are either full of eggs or sperm, or are thin and watery because they have spawned. In neither condition are they in good condition for marketing, but they are not poisonous. In addition, before days of adequate icing and refrigeration, the warmer months (without the "r") were months of greater oyster spoilage.

On the Pacific coast, particularly in California, cool summer temperatures usually inhibit spawning of the exotic species on which the commercial industry is based. If spawning does occur, the oysters recover their former condition rather quickly and are usually in marketable condition for part of the summer. However, the "R" superstition is so widely held, usually without knowledge of the basis for it and the different conditions prevailing on the Pacific coast, that demand falls off considerably during the summer.

The fall and winter months, particularly the Thanksgiving and Christmas holidays, and the Lenten season in the spring are the chief and traditional times when oysters are consumed. This consumption pattern is true for California as well as other parts of the country.

Marketing, 1870-1910

Eastern Oysters

The California oyster industry in the period 1870-1910 was concentrated in San Francisco Bay and the city of San Francisco was the principal oyster market. Small sailboats daily unloaded boxes of shell oysters from the beds off San Mateo at the wholesale establishments maintained in the city by the oyster growers. Some were retailed di-

rectly by the grower Moraghan, in his restaurant stalls in the California Market (Townsend, 1893, p. 357), but most were sold wholesale to hotels, restaurants, retail seafood dealers, and institutions.

Some oysters were sold in the shell, but most were opened in the wholesale houses, packed in tins, and covered with ice. In this state they were distributed not only within the city and to nearby towns, but to large towns on the Pacific coast from Victoria to San Diego and as far inland as Salt Lake City and Denver. Some were even shipped to Honolulu (Collins, 1892, p. 154; Townsend, 1893, p. 357; Wilcox, 1895, p. 207 and 1902, p. 564). Oysters were apparently "in season" during the entire year in San Francisco with summer sales and prices holding up well (Townsend, 1893, pp. 351-354).

The oyster supply seems, in general, not to have been in excess of demand. This fact, along with the two-company production monopoly after 1885, made for a non-competitive market and price stability from year to year. The growers had the further advantage of being able to hold excess oyster production off the market for a limited time but growth beyond about 4 years lessened the oyster's value, as small oysters were preferred.

Ingersoll (1881, p. 203), writing before mergers had reduced the number of growers to two, described a different market situation. He said that sharp competition brought oyster prices down, although they were still a luxury food. When fresh eastern oysters were first available, they sold for as much as $15 per hundred, but by 1880 prices ranged from $1 to $2.50 per hundred according to grade. However the decline in price may reflect greater availability during the latter part of the 1870-1880 period, as much as a sharply competitive market. Oystermen did not begin to import large quantities of seed until about 1875, and these oysters were not available for the market for 2 to 3 more years. Unfortunately it is impossible to know the exact nature of trends in this early period because production figures are not available before 1888.

For a number of years after 1880, prices did not seem to change substantially. Townsend (1893, p. 355) mentions a wholesale price of $4 for a box of 200 oysters in the shell. He states that on the east coast, choice oysters cost about $1 per hundred. Between 1904 and 1912, prices rose, perhaps due to scarcity of oysters resulting from failing production. However, between 1912 and 1915, while production continued to decrease, there was a break in prices to a figure lower than any since 1888.

Native Oysters

When eastern oysters raised in San Francisco Bay came into the market, the trade in native oysters from Washington and Oregon fell off drastically. The *San Francisco Bulletin* (March 22, 1879) states that whereas large schooners had formerly been employed in the Shoalwater trade, no vessels were currently engaged on a regular basis.

However, while eastern oysters came to dominate the industry in San Francisco Bay, there remained a place in the market for native oysters from Washington and Oregon; local natives, on the other hand, were considered inferior and did not enter the commercial market. San Francisco growers continued to bring native oysters from Washington

(Shoalwater Bay and Puget Sound) and Oregon (Yaquina Bay). The Morgan Oyster Company is reported to have had a large area of tidelands in Shoalwater (Willapa) Bay devoted to cultivating native oysters which it shipped to San Francisco. Some were marketed immediately while others were held in the beds, along with eastern oysters, and sold as demand warranted (Townsend, 1893, p. 357).

Before fresh eastern oysters became available in San Francisco, native oysters sold for as much as $16 per sack of 1,000. By the mid-1870's their price was forced down to $4 per sack, and in 1880 they sold for only $2.50 per sack (Ingersoll, 1881, p. 203). At $2.50 per sack they cost about half as much as eastern oysters. This price relationship was generally maintained throughout the remainder of this period (*Overland Monthly,* June 1894). Despite this lower price for native oysters, greater numbers of eastern oysters were sold, an indication of the preference for them.

Present Marketing

Marketing arrangements vary among California oyster producers depending partly on their volume of production and partly on their location. Tomales Bay and Drakes Estero oystermen, 1 to 2 hours from most of the San Francisco Bay Area, depend almost entirely on this market. The other two larger producers are about 200 miles from markets of any consequence and depend on arrangements that will provide widespread distribution of their larger volume of production.

The two producers on Tomales Bay, the Tomales Bay Oyster Company and Jensen's Oyster Beds, sell directly to the consumer. Jensen sells some of his oysters in a small cafe on the shore adjacent to the beds. Other oysters are sold to customers who take them home either in the shell or shucked. The shucking is done at the time of sale at an outdoor sink adjacent to the cafe.

The Tomales Bay Oyster Company has a larger volume of sales but also sells directly to retail customers. The company does not, however, maintain a restaurant or cafe. A small plant is located at the head of the wharf. There, an employee opens oysters, packs them in standard jars with clamp lids, and puts them in the small refrigeration room. In this way, sufficient shucked oysters are on hand to keep up with daily sales. Live oysters are also sold in the shell from the float moored at the end of the wharf. The eastern oysters held by the company are marketed in San Francisco.

Two other places on Tomales Bay, restaurants at Nick's Cove and Tomales, sell oysters to take out or consume on the premises. These are supplied by the Drakes Estero producer, and the amounts are not large.

The sales arrangements of the Tomales Bay producers are well suited to their scale of operations, but their success is somewhat remarkable in view of the location of the beds. Although the Tomales Bay beds are the only ones in California near a major center of population, they are not readily accessible. The local population is very small. Petaluma, with a population of 14,000 in 1960 is about 20 miles away, while San Francisco is about 55. Nevertheless people from all parts of the San Francisco Bay area drive many miles over a narrow, winding road to buy oysters from the beds. Weekend tourists and sportsmen are also

customers. The strong consumer desire for absolutely fresh shellfish is the principal explanation for the success of this marketing arrangement.

Marketing arrangements at Morro Bay are quite simple. Although there are three producers, one of them, the El Morro Oyster Company, buys and processes most of the oysters. Ninety-five percent of the Morro Bay oysters are sold to one customer, a grocery chain with many branches in California and other states. This company sends its own refrigerator trucks to pick up the orders at the plant and distributes them to its various retail stores, chiefly in central and southern California. Morro Bay is not near a large population center, but it is the nearest oyster growing area to the large Los Angeles market, and many of its oysters are sold there. The remaining five percent is sold locally. There is a considerable demand for seafood in Morro Bay restaurants.

Oysters raised in Drakes Estero and Bolinas Lagoon are sold to various San Francisco wholesale seafood dealers. The fresh packed oysters are trucked to San Francisco by the producer and delivered to the wholesalers, who in turn distribute them to retail dealers, most of whom are in the San Francisco Bay area.

The marketing arrangements of the largest producer in the state, Coast Oyster Company of Eureka, are more elaborate. This company has a sales broker in the San Francisco Bay area. Orders for oysters are placed with the broker who teletypes or telephones them to the Eureka plant. All sales of Humboldt Bay oysters are handled through the broker. Orders come from wholesale seafood dealers in the larger cities, particularly San Francisco, Los Angeles, and Sacramento, a grocery chain, the United States Army, and local fish dealers and restaurants.

The grocery chain picks up its oysters at the plant in its own refrigerated trucks. Common carrier trucking firms transport the other oysters. The wholesale seafood dealers distribute oysters to retailers in their areas, but few are sent beyond the main population centers.

Market Conditions

The brokerage firm handling sales for the Coast Oyster Company of Eureka estimates that 90 percent or more of its sales are made in California. Small amounts are shipped to points outside the state, especially to southern Oregon, Arizona, New Mexico, Texas, and Oklahoma. Orders from mountain and mid-western states are sent to Washington where a branch of the same brokerage firm handles sales for the plants at Willapa Bay, Puget Sound, and Gray's Harbor. The larger production in Washington provides more oysters for out-of-state shipments.

In the fall of 1956 when Humboldt Bay oysters came into the market, the volume of oysters produced in California increased by about 250 percent over the previous year, and nearly doubled in 1957. The brokerage firm undertook a campaign to develop a market for this increase and found the greater part of the increased production was absorbed in areas where oysters had previously been sold and only 20 percent of the sales increase occurred in new market areas. The firm felt at that time that more oysters could have been sold if they had been available. Increases in production since 1956 have found a ready market within the State.

Because the California oyster production could be consumed entirely within the State, and producers need not depend on out-of-state markets to dispose of their product, they do not compete to any extent for markets with other producing areas. Shipments made to southern Oregon enter the sales area of Washington and Oregon producers, and shipments made to southwestern states enter the sales area of Gulf states producers; however, the volume of California oysters shipped to these states is small.

The supply in the California market does not consist entirely of locally-produced oysters. Other fresh oysters come from Washington and the Atlantic coast; however, eastern oyster imports have become negligible in recent years. According to trade estimates, Washington producers today supply about 35 percent of the California market. Washington producers absorb the freight differential in order to sell at the same price offered by California producers.

When Pacific oysters became available in California in the 1930's, their lower price and greater abundance soon made them dominant over eastern oysters in most parts of California *(Pacific Fisherman,* April 1939, p. 77). They did not make much headway in the Los Angeles area where eastern oysters had long been imported. In 1941 it was estimated that eastern oysters still supplied 60 percent of the Los Angeles market and 20 percent of the San Francisco market *(Pacific Fisherman,* An. Stat. No., 1941, p. 271). Since then the growing scarcity and greatly increased price of eastern oysters has limited direct competition between these two oysters. In the California market today, Pacific oysters wholesale for $4.95 per gallon; eastern oysters, for about $9 per gallon f.o.b. Baltimore; and Olympia oysters for about $27 per gallon.

In the California market, eastern and Olympia oysters are largely used for cocktail or half-shell dishes to which the large Pacific oysters are not suited. The smaller oysters are chiefly available in restaurants, where the three species vie for the customer's choice. Oyster fanciers usually prefer one kind over the others. The choice may be made on the basis of whether the customer wants his oysters raw or cooked, or whether he is willing to pay more for an Olympia oyster cocktail than for one made of eastern oysters, or whether he will pay more for a Hangtown Fry made of eastern oysters than for one made of Pacific oysters. However, only in some restaurants in the major fish market areas of Los Angeles and San Francisco are all three oysters available in season. In most parts of the State, if oysters are on menus at all, they are Pacific oysters.

In the retail market the eastern and Olympia oysters are available only in limited quantities, in a few highly specialized fish markets.

The other shellfish that compete with fresh Pacific oysters are shrimp and crab. In the San Francisco Bay area shelled shrimp generally retails for $1.90 per pound. The retail price of crab meat averages $1.80 per pound. A 12-ounce jar of oyster meat sells for about 65 cents in most retail stores, making the price per pound about 88 cents. However, the products are not strictly comparable because of the high water content of oyster meat, much of which cooks out causing oysters to shrink by about one-third. If the price is increased by one-third, to $1.18 per pound, it still compares favorably with that of the other shellfish.

The price of oysters compares less favorably with the prices of various kinds of fish—in the San Francisco Bay area salmon retails for about 99 cents per pound; swordfish, 79 cents; halibut, 69 cents; seabass, 79 cents; cod fillet, 49 cents—but the comparison is less unfavorable when the amount needed per serving is taken into consideration. A 12-ounce jar of oysters for 65 cents will yield two servings, especially if the oysters are made into stew or a casserole as is commonly done, while at least a pound of fish is needed for two servings. Thus in terms of purchase for a meal, Pacific oysters are less expensive than the higher priced kinds of fish.

Pacific oysters can be compared with red meats in the same manner. It would be difficult to find lamb or veal chops for two persons for as little as 65 cents. The oysters for a casserole for four people would cost $1.30 or perhaps $1.95, while steak or roast beef for four people would cost much more. Although Pacific oysters have special uses, their price is generally in line with other fish and meat items rather than with the higher priced cocktail oysters indicating it is not a luxury food, at least on a price basis.

Other factors bearing on the market position of fresh Pacific oysters produced in California are the availability of canned and frozen fish and shellfish, particularly canned and frozen oysters. In the absence of a detailed market study, the relationships among the sales of fresh, frozen, and canned oysters is known only in a general way, but it can be said that where fresh oysters are available they are preferred to canned oysters even if their price is higher, and this is probably true of frozen oysters as well.

A large seafood canning company on the Pacific coast estimates that about one-half million cases of canned whole oysters are consumed in California each year. This represents about 6 million pounds of oyster meat, considerably more than the 2.2 million pounds of fresh Pacific oyster meat consumed. In addition, canned oyster stew is an important item of sale. The wholesale price of canned oysters is about $4 per gallon for the imported Japanese product and $5.30 for the domestic product, making Japanese canned oysters cheaper and domestic canned oysters more expensive than fresh Pacific oysters sold in California. The trade estimates that of the canned oysters marketed in California 25 percent are imports from Japan, 25 percent are eastern oysters from American Atlantic and Gulf growing areas, and 50 percent are Pacific oysters canned in Washington.

Japanese canned oyster imports have been growing, and the 25 percent price differential between the United States and Japanese packs has caused distress to United States packers. One possible result of this is noted in *Pacific Fisherman* (October 1958, p. 48) with the statement, "The immediate result of the rising tide of canned oyster imports promises to be a switch on the part of several Pacific Coast operators out of canning and into the fresh oyster trade. This is expected to result in a substantial increase in the amount of fresh oysters available for market in the Pacific oyster sales territory."

In 1955, the United States Congress reduced the tariff on hermetically sealed canned oysters from 8 to 6 cents per pound (Wallace, 1955, p. 12). Lobbyists for the United States oyster industry have sought but failed to achieve an increase in the tariff.

The consumption in California of large amounts of higher-priced U.S. canned oysters does not necessarily mean they are preferred over fresh oysters but rather may reflect the fact that they are available in greater quantities throughout the whole year and are more widely distributed.

Frozen oysters and oyster stew are relatively new in the California retail market. Three brands of frozen Pacific oysters produced in Washington are sold in California. In some areas, frozen eastern oysters are available. A San Francisco wholesale seafood dealer has introduced a brand of frozen, breaded eastern oysters from the Chesapeake area. However, there is not, at present, a large demand for frozen oysters in the west, where fresh oysters by tradition are preferred. Wholesale prices of frozen Pacific oysters from Washington are about 46 cents per 12-ounce package, slightly cheaper than fresh oysters.

A large oyster freezing plant, accommodating 300 openers, is being brought into operation in Hiroshima, Japan. Its production is intended chiefly for the United States market.

Another form of oysters available in California is the smoked oyster, but it is used exclusively as a snack or *hors d' oeuvre* food so it does not compete with the fresh Pacific oyster. None of the oysters produced in California is smoked, and most of those on the market are imported from Japan.

The discussion of supply and prices of California oysters in relation to competitive food items sheds some light on the present and future demand for this product. However, the taste for oysters, generally recognized to be an acquired one, is a major factor in the demand for them. While many people would reject oysters, or not even try them, if they were readily available, it is nevertheless probable that the market for them would be broadened were they made more widely available.

The long-term decline in United States oyster production, and continued population growth means a large part of the population is unfamiliar with oysters. This is a very different situation from the one prevailing during a large part of the 19th century, particularly on the Atlantic coast where oysters were cheap, plentiful, and widely consumed. Exploitation of extensive natural oyster beds in many bays along the east coast made it possible to produce an abundance of oysters cheaply. Although oyster cultivation was introduced at an early date, especially in the New England and middle Atlantic states, to make up for the depleted natural beds, production gradually declined. This decline has been accelerated during the last several decades by pollution and the depredations of many pests, and in recent years by diseases. Declining production has brought higher prices, taking the oyster out of the reach of many people and thus reducing demand. Moreover, as Woodward (1955, p. 187) says, "high prices not only reduce the amount of the product purchased immediately, but also, from lessened use, change the habits and tastes of the consumers."

Oysters were neither so plentiful nor so cheap in the San Francisco Bay area in the 19th century as they were on the Atlantic coast, but they were nevertheless a popular food in the San Francisco area. The principal reasons for the establishment and success of this industry were the familiarity with and desire for oysters on the parts of the early American settlers, most of whom were from the east coast.

The decline of the industry after about 1910 due to unfavorable conditions in San Francisco Bay meant a relative scarcity of fresh oysters in California, which persisted until about 5 years ago. For about 45 years, the only fresh oysters consisted of limited amounts from the east coast, supplemented during the 1930's and 1940's by small shipments of Pacific oysters from Washington and those of a few small California producers.

Because of the long period of scarcity, and immigration of many people from midwestern states, the California market was for the most part unaccustomed to oysters, and the early distributors of Pacific oysters had to build up a new market. Producers at Morro Bay and Elkhorn Slough had trouble marketing their oysters in the 1930's partly for this reason. The element of the population that had been familiar with eastern oysters generally rejected Pacific oysters because of their large size, darker color, larger black mantle, and a less familiar flavor. Nevertheless, during the 1930's, 1940's, and early 1950's Pacific oysters did become established in the California market and producers and distributors have not encountered any serious difficulty marketing the larger volume produced since that time.

SUMMARY

The California oyster industry, after a long period of quiesence from about 1910 to 1955, has entered a period of increased production that probably will be sustained. The companies responsible for this growth feel they have demonstrated that relatively large-scale oyster culture can be successfully carried out in their areas, and are confident this will continue to be true. This optimism appears well founded in that the companies have had long experience in the oyster business. They serve a region where the population is increasing rapidly, and this, combined with the lack of other large California bays suitable for oystering, indicates market conditions will be favorable and stable.

It is not likely the two large bays not presently used for oyster culture, San Francisco Bay and San Diego Bay, will be sufficiently cleared of pollution in the near future to enable the industry to utilize them. The upper part of San Francisco Bay, San Pablo Bay, is not considered polluted but storms, floods, and silting are often severe there, and despite interest in developing an oyster industry on its extensive mudflats, the prospect of success seems questionable.

Tomales Bay has been declining as an oyster producing center recently, but in the future a more vigorous company may fully develop the limited tide flats at the head of the bay. Much of Tomales Bay is deep and could possibly be more fully utilized for growing oysters by the Japanese method of hanging culture.

Many small bays and lagoons along the California coast, such as Newport Bay in southern California, which might have been used to grow oysters, have been given over to other uses, chiefly recreation.

The industry is not seriously plagued with destructive pests which it cannot control, nor pollution from domestic or industrial sources. There have been no oyster diseases such as those causing considerable losses to oystermen on the east coast.

It seems likely, given favorable ecologic conditions, a stable source of seed oysters, experienced oyster companies, and a growing market, that the California oyster industry will be able to continue the high level of production achieved in the last few years and even make some gains. However, the limited remaining areas where oyster culture is feasible preclude large-scale expansion in the near future.

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